UNITED STATES ARMY
X-RAY MANUAL

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AUTHORIZED BY THE SURGEON-GENERAL OF THE ARMY

Prepared under the Direction of the Division of Roentgenology

[219 ILLUSTRATIONS]

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INTRODUCTION

THIS manual has been prepared under the direction of the Surgeon General of the Army to serve as a guide to roentgenologists who are doing the x-ray work in our military hospitals, and as a textbook for instruction in military roentgenology. It will supersede the small U. S. Army X-Ray Manual which was hurriedly prepared at the beginning of the war to facilitate the instruction of the many inexperienced men who, of necessity, had to be trained to do x-ray work.

The manual is not intended to be a complete treatise on roentgenology, but in the portion devoted to x-ray diagnosis the aim has been to state as concisely and clearly as possible the facts that have been established by experience, and to avoid all controversial points.

There is, of course, no clear line of demarcation between military roentgenology and roentgenology of civil practice. It is the same art, but practiced under different circumstances and, sometimes, with an entirely different type of apparatus. The principal aim in the preparation of this manual and in the courses of instruction carried on by the Medical Department has been to familiarize the already experienced roentgenologist with the apparatus with which he is to work, and to give him additional instruction along any lines in which he may be deficient. The need for a large number of roentgenologists, however, has rendered it necessary to train for this work physicians who have had little or no previous experience and, for this reason, it has been necessary to cover in the manual practically all phases of roentgenology.

The parts of the manual devoted to the localization of foreign bodies and to a description of new apparatus deserve special attention. The localization of foreign bodies occupies most of the roentgenologist's time in the forward hospitals, and he must thoroughly master the methods described. The new apparatus described in Chapter III has been developed either just preceding or subsequent to the entry of our country into the war. It differs in many respects from the apparatus in use in civil hospitals. Some of this new apparatus, such as the portable and the bedside unit, have certain limitations. These must be recognized and must not be exceeded. It should not be concluded, however, that because there are certain limitations the apparatus is of little value. For instance, the maximum current to be obtained from the bedside apparatus is five milliamperes, but this low milliamperage is rendered very effective by the constant and properly selected voltage and the quality of the plates resulting from the fine focus of the special type of Coolidge tube employed. For bedside work in many of our large hospitals this apparatus has been found invaluable.

The great importance of the x-ray in military surgery and medicine has been established so that the roentgenologist has a position of much responsibility. He must remember, however, that his work is valuable only in so far as he assists the physician or surgeon in arriving at correct conclusions, and that this can be accomplished only by mutual coöperation. The roentgenologist does his part by presenting to the surgeon accurate findings carefully recorded in a usable form. After he gains the confidence of the surgeon in the accuracy of his work and the soundness of his judgment, the exercise of a little tact will always make it possible for him to secure full coöperation and thus give to the x-ray examination its maximum value.

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X-RAY PHYSICS

Introduction.—The following brief notes on the physical aspects of the apparatus likely to be used in military roentgenology have been written with the hope that their study might enable the roentgenologist to prepare for service in less time and be better able to utilize the apparatus with which he is compelled to work. With the belief that brief reasons as to why things are done are good guides in operation, rather more explanation of fundamental principles has been given than is usually included.

X-Rays.—The roentgen or x-rays are produced by an electric current in a glass-walled vacuum tube. Such a current is due to the projection of minute electric particles (electrons) from one metal terminal, the cathode, to another metal terminal, the anode or target. The x-rays originate at the point of impact of the electrons on the target and travel out from their origin in all directions except where dense material obstructs or prevents their passage. When passing through bodies made up of various parts differing in density, some of the rays that enter the denser portions are permanently cut out and a new distribution of intensity in the beam results.

The presence of x-rays must be determined by some of

the effects they produce when acting on material bodies. These actions are:

1. Effect on the emulsion of a photographic plate.
2. Excitation of light in certain crystals (fluorescence).
3. Rendering gases conducting to electricity (ionization).
4. Stimulating or destructive action on living cells (biological action).

The first, second, and fourth of these are of fundamental value in the medical and surgical uses of the rays. The third has been very useful in the study of the radiation.

These rays do not excite vision on reaching the retina of the eye, but are capable of originating light in certain crystals. A uniform beam, falling on a piece of cardboard covered with such crystals, would cause uniform illumination. If regions of unequal material density have been traversed by the beam before reaching the screen (fluoroscope), such dense portions will show as areas of lesser brightness or, as we say, will cast shadows. In the same way, a photographic plate or film sufficiently acted upon by such rays will, on development, give areas of unequal blackening, marking out the *projections* of volumes in the body whose densities differ from those surrounding them. On the fluoroscopic screen, dense bodies show as *dark* areas; in a photographic negative, they show as *light* areas.

It has been shown by various investigations that x-rays are identical in their nature with light and electric waves, except that their wave lengths are very much less than even the shortest light waves. On account of this extremely short wave length, the effect of matter upon their propagation is quite different from that in the case of longer waves. Such short waves are only produced by a change in the velocity of electrons taking place in intervals

of time too short to be easily conceived. The gamma rays of radium, etc., are simply rays due to the sudden *starting* out of electrons by atomic breakdown. They may be shorter or longer than the x-rays we use in fluoroscopy or in radiography.

The term ray is used to designate two distinct types of phenomena. One, a projection of small particles by atomic disintegration, as beta and alpha rays. The other refers to the transfer of physical effects by the agency of wave motion. In this class we have light, gamma and x-rays.

It may be also noted here that gamma rays are of the same physical nature as x-rays, but some gamma rays are of shorter wave length than the x-rays we are able to produce at the present time.

The following general properties of this radiation should be understood in order to facilitate its intelligent application.

Paths.—These rays travel in straight lines into, through, and out of material bodies, except where the atoms themselves cause scattering. They *cannot be directed* by mirrors or lenses for purposes of optical focus or concentration, as is done with light. The slight amount of regular reflection by the uniformly spaced atoms in crystals is too small to be of any importance to the roentgenologist.

Velocity.—The rays travel out from the target at the same velocity as light or electric waves.

Energy.—The actual energy involved in an x-ray beam is small compared with that expended in getting it started; only a few parts in a thousand of the energy supplied is converted into x-rays.

Scattering.—X-rays are scattered in passing through matter exactly as light is scattered in turbid water, fog,

paraffin, etc. Only a part of a beam is thus scattered, the remainder passing straight through or being absorbed. Scattering confuses shadows on screen or plate in a very troublesome way.

Passage Through Matter.—When rays pass through material, the substance is called transparent to the radiation. If little or no radiation gets through, we say the material is opaque to this radiation. The terms transparent and opaque refer to the action of the material with reference to a specific type of radiation. If one arranges a variety of substances of like thickness in the order of *increasing* density, their *opacity* to x-rays will be nearly in the same order. But this will vary somewhat according to the quality of the x-ray beam considered. That portion of the incident radiation neither transmitted nor scattered is changed into heat or, as we say, absorbed in the material. We then say that absorbing power increases with the density of the absorber. This absorbing power is best expressed as the fraction of the rays absorbed by a definite thickness of material. Thus, if 1 cm. of water should reduce a particular radiation so that the emerging beam is half as effective as the entering one, we might say this radiation has a *half value* layer of 1 cm. of water. Two centimeters of water would transmit only 25 per cent of the incident beam or that reaching the surface proximal to the tube.

The quality of short wave length and high penetration can be secured only by means of high voltage operation. (See penetration, p. 46.)

Electrons.—The modern concept of atoms involves the idea of their general electrical constitution. From any atom there may be abstracted one or more small negative charges, all precisely alike, whose properties are in no wise

dependent on the atom from which they come, and all are quite capable of existence by themselves without the presence of the remainder of the atom. These little bodies have been variously named as corpuscles, cathode rays, beta rays, electric-ions, etc. The common designation of electron is derived from the latter. An electron is able to respond to electric force and to acquire velocity under such force action. When in motion, they show all the characteristics of an electric current.

The main physical features of electrons are:

1. Their fixed and definite negative charge.
2. Their extremely small mass and volume.
3. The extreme speed they may acquire.

Production of X-Rays.—Roentgen or x-rays originate in any region where the velocity of electrons is suddenly changed. In the radio-active breakdown of atoms, this change is a sudden *acquisition* of velocity, and the gamma rays are produced. In x-ray tubes, the high-speed electron is stopped in its flight by the interposition of a target metal of high atomic weight placed in its path, and x-rays result from a *loss* of velocity.

The problem of x-ray production for our purpose, then, resolves itself into four parts.

1. The separation of electrons from atoms.
2. Giving them high speed.
3. Concentrating them on a small area.
4. Stopping them with sufficient suddenness.

The first of these is accomplished in one of two ways. In the tubes containing a *small amount* of gas, electrons are secured in part by high electric field, but to a much greater extent by the disruption of atoms due to the moving electrons and by the x-rays themselves. In the more

recent hot cathode tube (Coolidge), electrons are set free from the atoms in a tungsten wire by the action of heat. In the former, the number of available electrons is rather hard to control, while in the hot cathode tube this offers no difficulty.

In order to secure high speed (one-half to one-third the velocity of light) a high voltage must be available, and the electrons must all be urged toward the same small area in order to get sharp shadows. The concentration on the target is secured by proper design of the electrodes and their proper position in the tube. In all cases the path to be followed must be quite free of gas in order to avoid obstruction.

The choice of metal as a barrier is of great importance, and only a few elements satisfy the conditions. Every fast-moving electron has some mechanical energy and this goes mainly into heat by impact; there results a great rise in temperature at the point of electron concentration. As radiographs and fluoroscopic images are purely shadow effects, a source of radiation starting from a point is very desirable. This high concentration of heat will melt any target material at high power operation. Only metals of high melting points can be utilized, such as platinum, tungsten, osmium, and iridium. Of these the first two are in common use, the tungsten to a great extent during recent years. High atomic weight is also desirable, and fortunately this goes with high melting points in the above metals.

General Instructions and Precautions.—1. *Excessive* exposure to x-rays results in serious injury to the skin. Such injury does not manifest itself at once but may develop some weeks later. To a degree, the action is cumulative, so that a single dose, in itself too small for

injury, may, when frequently repeated, be harmful. Read carefully the notes as to protection, page 194. While it is unwise to be over timid, it is much easier to prevent an injury than to cure it.

2. X-ray apparatus is expensive, and not only is it costly in money to repair damage, but even more important is loss of service from breakdown. Do not try to see how much current you can pass through a tube or how long a spark the transformer will give. Do not imagine that a tungsten target cannot be melted; it can, and very quickly.

3. Acquire the habit of observing whether high tension wires are sufficiently far from patient, assistants, etc., *before* you close the operating switch.

4. Make all tests of tubes, etc., on low power, when possible, and do not make unnecessary speed your ambition. When through work, throw all controls to low power.

5. Never test out a tube when the patient is in position.

6. Always see that current is passing through the filament of a Coolidge tube before closing the main transformer switch.

7. Do not imagine you can make plates of thick parts on very low spark gaps. It cannot be done, but you may get some very unfortunate experience trying it.

8. Remember that any current that passes across the spark gap or leaks from one line to the other along walls, etc., does not help to produce x-rays, although it may increase your milliammeter reading.

9. Try to develop a definite order and sequence in the various details of any examination. It will save time and prevent errors.

10. The only safe time to label a plate or film for identification is at the time of exposure.

11. Don't imagine that so and so's good plates are due to the particular machine he is using; and don't chase off after every new exposure "technique" you hear about. The fact that some individuals advocate one after another is ample evidence of their uselessness.

Electrical Terms.—Certain terms are used so frequently in all discussion of electrical matters that they are introduced at this point for convenience in reference.

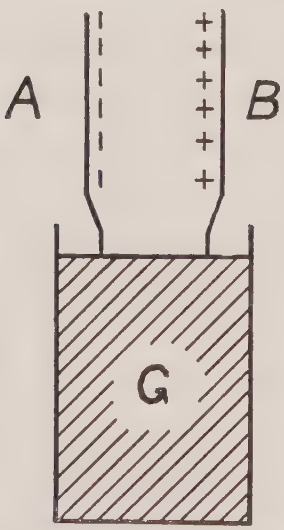


FIG. 1. Generator on open circuit.

Charges.—When any physical or chemical action breaks down the connection between an electron and the remainder of the atom, the electron constitutes the elementary particle of negative electricity. All negative charges are simply countless numbers of electrons kept away from the positive portions of the atoms from which they were separated.

Generators.—Generators do not create electricity. They take electrons and positive atomic remainders apart and push them in opposite directions against their natural tendency to keep and come together. Thus, if G, Fig. 1, represents a generator, A and B metallic plates connected to its terminals, A is covered with electrons and B with enough positive to neutralize the negative on A. If we call e the negative charge of one electron, and Q the total charge on A, N the number of electrons, then Q equals Ne, where N is an incredibly large number in most cases.

Voltage.—Electric charges separated as shown in Fig. 1, show: (1) a mechanical pull on the bodies *A* and *B*, (2) a decided tendency to pass between *A* and *B*.

A voltmeter does *not* measure electricity but something like a pressure or strain trying to pass a charge between two regions.

The Volt.—The volt is the unit in which the tendency of charge to move from one place to another is measured. The electrical tension between the terminals of a special cell (Weston or Cadmium cell) is taken by legal definition as 1.019 volts.

Current.—When proper external connections are made to the terminals of a generator there results a transfer of charge. If we could count the number of electrons passing on to *A* per second, say *n*, we would call *ne* the current passing through *G*. An electric current may then be regarded as a measure of the number of electrons passing per second. It must be observed that after *A* and *B* are charged as highly as is possible for the particular generator, there will be no further current, but the voltage is present. *We may have voltage existing and no current, but never a current without some voltage.*

The Ampere.—The ampere is the unit of electric current. It is legally defined as the rate of transfer of electric charge which deposits silver from a special solution at the rate of .001118 grams per second. The unit electric charge is the coulomb. Five amperes, for example, will transfer 40 coulombs in 8 seconds.

Resistance.—It requires but little voltage to move a big supply of electrons through some materials, while with others a very great voltage will cause but little electron movement. The former are named conductors; the latter, insulators. Note carefully that the difference is one of

degree, and that perfect insulators do not exist so far as high applied voltage is concerned. Thus, dry, clean glass may be considered an insulator for moderate voltages, but may conduct to a considerable extent at high voltage. The objection offered to the passage of an electric current by any material included in a circuit is called its resistance.

The Ohm.—The unit of electrical resistance. Legally defined as the resistance of a uniform column of mercury 106.3 cm. long and one square millimeter section at 0° centigrade.

Power.—The ability of the electric current to do work is termed its power.

The Watt.—The watt is the unit of electrical power. It is the power of a current of 1 ampere in a region where it loses 1 volt. The product, amperes x volts lost = power in watts; 746 watts are equivalent to one mechanical horsepower, and 1 kilowatt is therefore equal to about 1⅓ horsepower.

Derived Units.—The units given above are not of convenient size in all cases, and some modifications are in common use. The terminal voltage on the tube is high, and it is often expressed in kilovolts (1 kilovolt equals 1000 volts). The current ordinarily used through x-ray tubes is small and is expressed in milliamperes (1 milliampere equals $\frac{1}{1000}$ ampere). The power used to operate electrical devices is generally expressed in kilowatts, when the number of watts is large (1 kilowatt equals 1000 watts). One kilowatt maintained for one hour is named a kilowatt-hour.

As applied in particular cases, a 4 kw., 110 volt generator, is a machine that delivers 4000 watts at full load and is designed to operate at 110 volts. The full load

current would be $\frac{4000}{110} = 36.3$ amperes. If a machine gives 50 *milliamperes* at 70 *kilovolts,* the power delivered is $\frac{50}{1000} \times 70 \times 1000 = 3500$ watts, or $3\frac{1}{2}$ kw.

Measuring Instruments.—The electrical measuring instruments that may concern the roentgenologist are the ammeter and the voltmeter for *low tension circuits,* the milliammeter, and the kilovoltmeter for *high tension circuits.* Most kilovoltmeters are of little real value as they vary with the secondary current. The milliammeter is a most valuable aid to the work. It is often designed for two

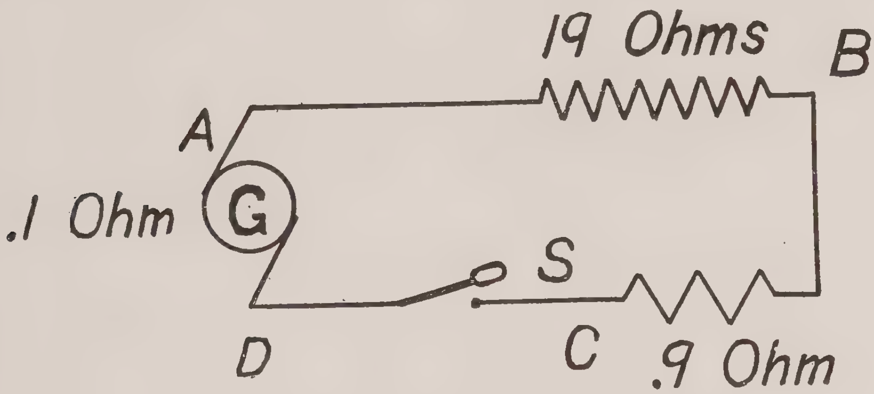


FIG. 2. Simple electric circuit.

ranges. From 0 to 15 ma. on one scale and 0 to 150 ma. on the other is the best for most work.

Do not try to draw 150 ma. when the meter is set for a maximum of 15 ma. If the pointer gets bent, due allowance must be made in reading.

Electric Circuit.—An electric circuit consists of some sort of a generator and a more or less complex conducting path between its terminals. Electricity *outside* a generator always passes from high to low voltage, and the current may properly be said to *lose voltage* en route from one generator terminal to the other.

Consider a very simple circuit, Fig. 2, consisting of a generator, *G;* generator resistance one-tenth ohm, two other

resistances as shown. The fundamental law of such a circuit is that if when the switch, S, is open we have, say 220 volts, then for any total resistance, R, we will have a current, on closing S, such that

Current x total resistance = 220, or in this case,
No. of amperes x $(.1 + .9 + 19) = 220$
Current, $I = \frac{220}{20} = 11$ amperes.

The voltage is used up as follows:

In the generator	11 x .1 =	1.1 volts
Between A and B	11 x 19 =	209.0
Between B and C	11 x .9 =	9.9
Total		220.0 volts

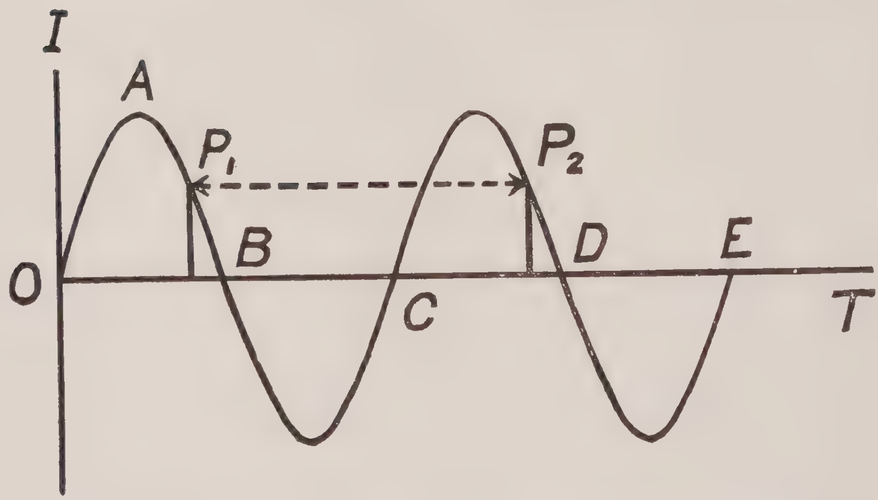


FIG. 3. Current-time curve of a simple a.c. circuit.

This relation is true for all circuits, viz., volts lost due to resistance of R ohms when a current of I amperes is flowing $= I\ R$.

Direct Current (d.c.).—When the electron-flow is in only one direction, the current is named direct. Dry cells, storage batteries, static machines, and d.-c. dynamos deliver

direct current. A current may be intermittent or pulsating, and still be called a direct current.

Alternating Current (a.c.).—When the electrons flow in one direction for a short time and then the flow decreases and a reverse flow occurs, we say the current is alternating. A.-c. dynamos are the only sources of true alternating current.

Such a current in its simplest form may be pictured by a suitable time-current diagram. In Fig. 3 time is shown as increasing from left to right.

$$\text{Let } OC = \frac{1}{60} \text{ second}$$

$$\text{Then } OC = BD = CE = P_1 \ P_2 = \frac{1}{60} \text{ second}$$

This current takes all its variable values once in 1/60 of a second, and repeats the operation 60 times in one second. It is designated as 60 cycle a. c. If drawn from a 220 volt service, its complete designation is 220 volt—60 cycle—alternating current of a certain number of amperes.

During the times *OB*, *CD*, *EF*, etc., current flows in the opposite sense to that during the times *BC*, *DE*, etc. Note that there are two *alternations* to each cycle, or 120 per second in this case.

X-Ray Current-Voltage Requirements.—At present x-ray tubes are used with currents varying approximately between 5 and 100 milliamperes, and at voltage running between 25 and 100 kv., i. e., 25,000 to 100,000 volts. This high voltage requirement cannot be met by simple d.-c. generators.

High Voltage.—The requisite voltage is secured by the use of:

1. The so-called static machine (direct but impractical).

2. The periodic *interruption* of a direct current through one coil, causing high voltage in a neighboring coil (induction coil).

3. Using a low voltage alternating current in one coil and getting a high voltage alternating in an adjacent coil (transformer).

The second device is still used to some extent, but has largely been displaced by the transformer in recent years.

The use of an induction coil or a transformer to increase voltage involves two distinct circuits, one connected through some control device to the supply line or generator, and known as the primary circuit; the other, insulated from the primary and connected to the tube terminals, known as the secondary circuit.

The primary always:

Is of relatively low voltage.
Is a moderately large wire.
Carries a current of some *amperes*.
Is reasonably safe to touch.
Requires good metallic contacts at all connections.

The secondary always:

Is high voltage.
Is quite a small wire.
Carries a current of some *milliamperes*.
Is unpleasant and often dangerous to touch.
Will pass current across loose connections or even through some insulating material.

The induction coil and a few transformers have both coils wound on hollow concentric cylinders, the primary within the secondary, and the space inside the primary coil is filled with thin iron sheets or wires. These are named open magnetic circuit devices.

Most transformers now in use have the iron in the form

of a closed rectangle, and the two coils wound so as to slip on the sides of this rectangle. These are known as *closed magnetic circuit* transformers.

The Gas Tube.—While a great variety of special forms of gas containing tubes have been introduced from time to time, the general form shown in Fig. 4 alone has survived for ordinary use.

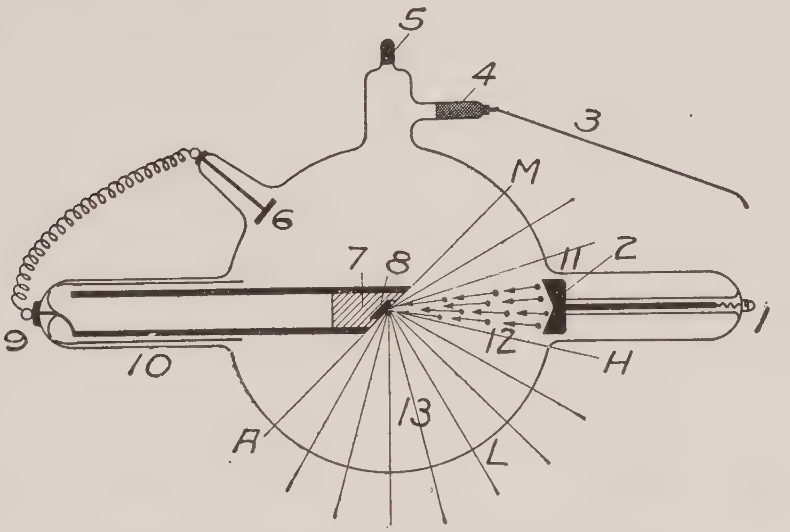


FIG. 4. Regular gas containing tube.

1. Negative or cathode terminal.
2. Cathode of aluminum.
3. Adjustable connections for softening.
4. Softening material.
5. Sealing off tip.
6. Auxiliary anode.
7. Copper block.
8. Tungsten button.
9. Positive or anode terminal.
10. Anode neck.
11. Cathode neck.
12. Cathode particles.
13. Path of x-rays.

A L M, Anterior hemisphere showing fluorescence.

The target material has a great influence on the behavior of the tube and the quality of the rays. The atomic weight must be high, as the fraction of cathode ray energy transformed into x-rays increases with increase of atomic weight. The melting point must be high or the metal will melt at the focus. It should conduct heat well, and must not vaporize readily below its melting point. The following table gives the approximate data relating to possible metals for this purpose. Taking platinum as a standard radiator:

Metal	At. Wt.	Amount of X-Radiation		Melting Pt.
Platinum	195.2	1.		1760. C.
Iridium	193.	.98		2300
Osmium	190.9	.97		2700
Tungsten	184.	.91	above	3000
Tantalum	181.	.90		2900

The essential features of *all* modern tungsten target gas containing tubes are shown in Fig. 4. Various minor modifications may be seen in tubes from different makers, but each part shown must be present in some form.

The cathodes may differ in shape, but only aluminum gives good results and long tube life. The mounting of cathode and target must be firm, and the position in the neck carefully chosen. The adjustable arm (3) is often absent, and a third wire is run to a variable spark gap connecting with the negative terminal of the machine. The auxiliary anode (6) has a great variety of forms; in many water-cooled tubes, and sometimes in others (6) and (10) are interchanged. Numerous special devices for conducting heat away from the target are in use and are

more or less effective. For treatment or for long fluoroscopic examination with this type of tube, water cooling is essential, and a good stream of air directed against the glass adjacent to the cathode is also of considerable assistance. A satisfactory tube must have a stable position of anode and cathode; all attempts to use an adjustable cathode have been unsatisfactory. The metal parts must be pre-heated and the tube itself heated during exhaustion. A well made and properly exhausted tube shows a good hemisphere on the anterior portion, and the remainder of the tube should show but little fluorescent light; a working tube should not be "flashy" or "cranky." When one attempts to operate a moderately hard tube at too low potential, this unstable state may result and either the voltage must be raised or the tube softened. The vacuum must be within fairly well-defined limits, averaging not far from .001 mm. pressure of mercury, and must be in some manner under control, if the life of the tube is of consequence.

The tendency of all gas containing tubes on low current is to "harden," i. e., to require more voltage for the same current, or, if the voltage is not changed, the current decreases. On operation above a certain power peculiar to each tube, the tube softens on account of heating; when this proceeds so far that the tube shows and maintains a purple glow marking out the cathode stream, it is useless until repumped.

Many devices have been used to soften tubes. The more common are the following:

1. A side tube containing mica, asbestos, etc., and through which a small discharge current may be sent, thereby liberating gas. (No. 4, Fig. 4.)

2. A special target is placed in a side tube to be bombarded by rays from a small auxiliary cathode.

3. A fine palladium tube projects through the walls of the tube; when this is heated by a small flame it allows hydrogen to pass into the bulb. This has been modified by Snook, where the tube is heated by a spark discharged from the operating transformer.

4. Heating the entire bulb. (Useless except in an emergency.)

5. A mercury-controlled porous valve allows air to pass slowly into the bulb when the inlet is not covered by the mercury (Heinz-Bauer).

2, 3, and 4 are rarely used in this country, although 3 (osmosis regulators) are sometimes seen outside the more useful Snook form.

The Coolidge Tube.—The great difficulty in the operation of the ordinary gas containing tube lies in the irregular supply of electrons and the impossibility of control of their development. When operated above very moderate power, the trend is always toward larger quantities of electrons and a consequent drop in penetration, unless the current is greatly increased, when a still greater supply is developed, so that there is no automatic self-protection of the tube.

Wehnelt found that a platinum ribbon coated with lime would allow of current transfer through a high vacuum at moderate voltages. Several attempts to use such a cathode for x-ray tubes were unsuccessful, and no modification of the standard tube appeared until it was found by Richardson and others that electrons were emitted by hot metals.

The simplest application of this principle to x-ray development has been worked out by Dr. W. D. Coolidge in the Research Laboratory of the General Electric Company at Schenectady. In this tube, the cathode is a spiral filament of tungsten wire, *A*, Fig. 5, heated to a high tem-

perature by a current from an *insulated* storage battery, or by a special transformer. The form of electrostatic field needed for focussing the electron stream is fixed by a small molybdenum cylinder, *B*, within which the cathode is placed. The target is usually a solid piece of wrought tungsten mounted on a molybdenum rod, around which collars are placed to distribute the heat conducted from the target.

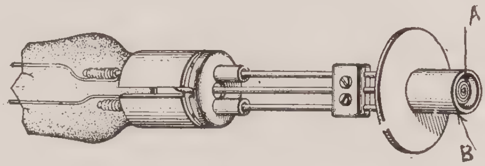


FIG. 5. Coolidge cathode construction.

Fig. 6 shows the Coolidge tube.

1. Cathode terminal.
2. Electron focusing cone.
3. Solid tungsten target.
4. Molybdenum supporting rod.
5. Anode terminal.

In order to operate properly, it was found that the highest possible vacuum must be attained. Not only was the greatest care required in pumping, but the metal

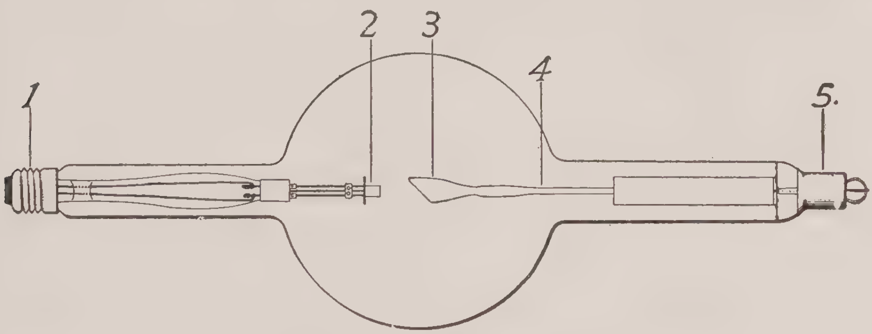


FIG. 6. Coolidge tube.

parts had to be freed from occluded gas by heating in a vacuum nearly to their melting point. In this tube there is no source of electrons except from the hot filament, and as this supply *depends only on the temperature of the filament*, the operator has perfect control of the number of available electrons by simply changing the auxiliary

current. A small transformer is now generally used to supply low voltage for the filament current. Connections are as shown in Fig. 7. The winding connected to the filament must be well insulated from case and primary winding.

The *current* through the tube cannot be increased after

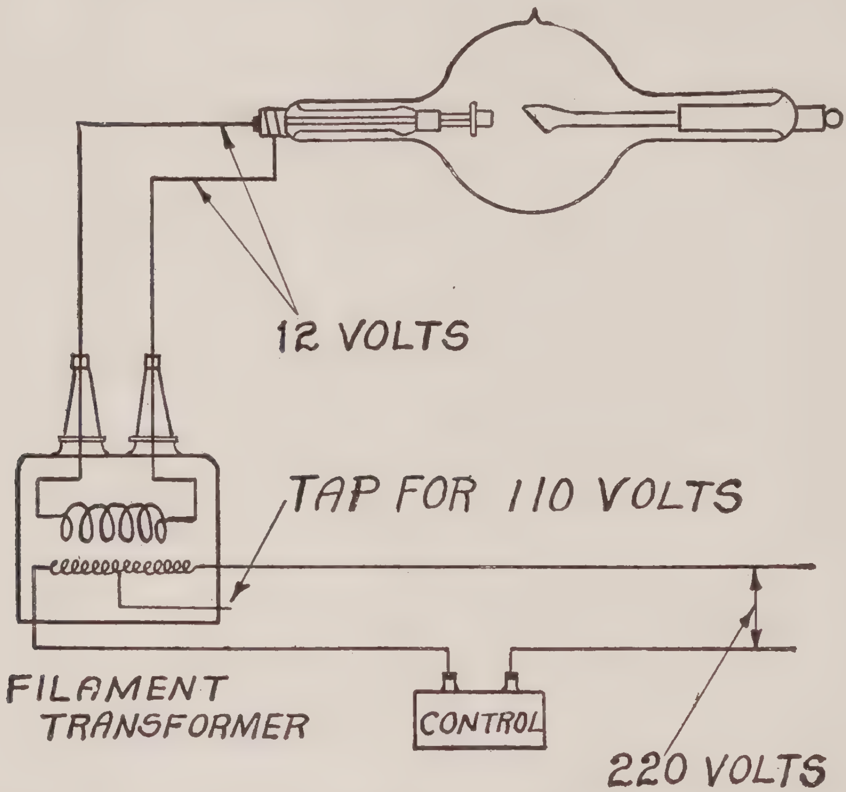


Fig. 7. Wiring diagram for step-down transformer to supply current for filament of Coolidge tube.

the supply of electrons is entirely utilized, no matter how much the *voltage* is raised. This maximum current for each particular filament temperature is named the *saturation* current, and until this is reached the voltage maintained between cathode and target may be too low for use. So long as the negative current reaching the tube does not exceed the number of electrons emitted per sec-

ond multiplied by the charge of each electron, there can be no charge piled up on the electrodes—i. e., no effective terminal voltage.

No Inverse.—A further valuable feature of the tube is its inability to transmit inverse *so long as the focal spot is not too hot.* On account of the increased strain on the glass, when inverse is present, it is well to include a valve tube when operating on a heavy coil.

Penetration Limits.—The highest operating voltage on the present tubes is about 100 kv., as measured on a special electrostatic voltmeter. This refers to "effective" voltage; the peak voltage is larger than this.

No doubt this can be increased by modification of the design, but insulation difficulties and danger of puncture will be increased as higher voltages are used. Such high penetrating rays as may now be reached are *not* useful in fluoroscopic work or in radiography, partly on account of the enormous amount of scattered radiation developed in the tissues of the body. Such scattered and corpuscular rays may, however, be useful in therapeutic work. Very soft rays may be produced in great abundance if the glass will allow them to pass out. Attempts to use too soft rays in radiographic work are always fraught with grave danger.

No Fluorescence in the Glass.—In marked contrast to the usual tube, there is no fluorescence of the glass walls except a slight illumination in the anode neck. Sometimes a minute chip in the glass or a slight evolution of tungsten vapor will give a momentary flash of green, but on further operation at moderate power this disappears. The bombardment of the walls of the tube by electrons reflected from the target or scattered from the gas atoms in the gas containing tube is the cause of the fluorescence and of a very considerable amount of soft radiation

originating in the glass. As there is in a gas tube as large a supply of positive ions as of negative, continual recombination results, and no negative layer can form on the glass walls to prevent bombardment by scattered and reflected electrons. In the Coolidge tube the absence of positive ions probably allows the accumulation of a negative charge on the glass, and as soon as established this layer repels electrons and the glass is no longer a target.

New Form of Coolidge Tube.—The ordinary form of Coolidge tube will operate satisfactorily without a rectifier *if the focal spot is at a temperature below that at which it gives off an appreciable number of electrons.* It follows that part of the problem of eliminating the rectifier is keep-

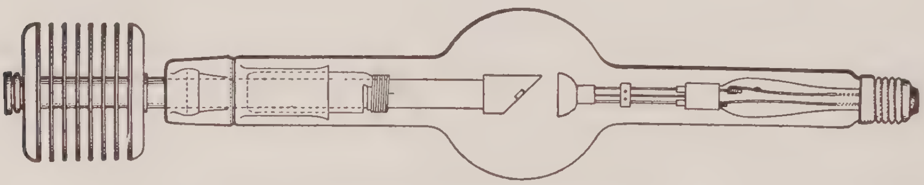


Fig. 8. Radiator type of Coolidge tube.

ing the target cool. A new form of tube which will help greatly in this mode of operation has recently been developed by the General Electric Research Laboratory, Fig. 8. The target is a tungsten button set in a heavy copper backing which is continuous with a large copper rod extending out of the tube neck. To this are attached a series of discs acting as radiators. Operated within limits set by the manufacturers, this tube suppresses completely each alternate half wave and may be operated direct on a *suitable transformer.* At present these are designed for 10 ma. at a 5-inch gap for radiographic work, and for 5 ma. at the same gap for continuous duty in fluoroscopy. The wiring diagram then becomes very simple and easily understood.

In Fig. 9 are shown a current-time curve and a voltage-time curve for the self-rectifying tube. In the latter *OA* is the working peak voltage which determines the tube radiation, and *BC* is the peak voltage of the suppressed wave which would give the spark gap reading.

A transformer should be used which will not vary its

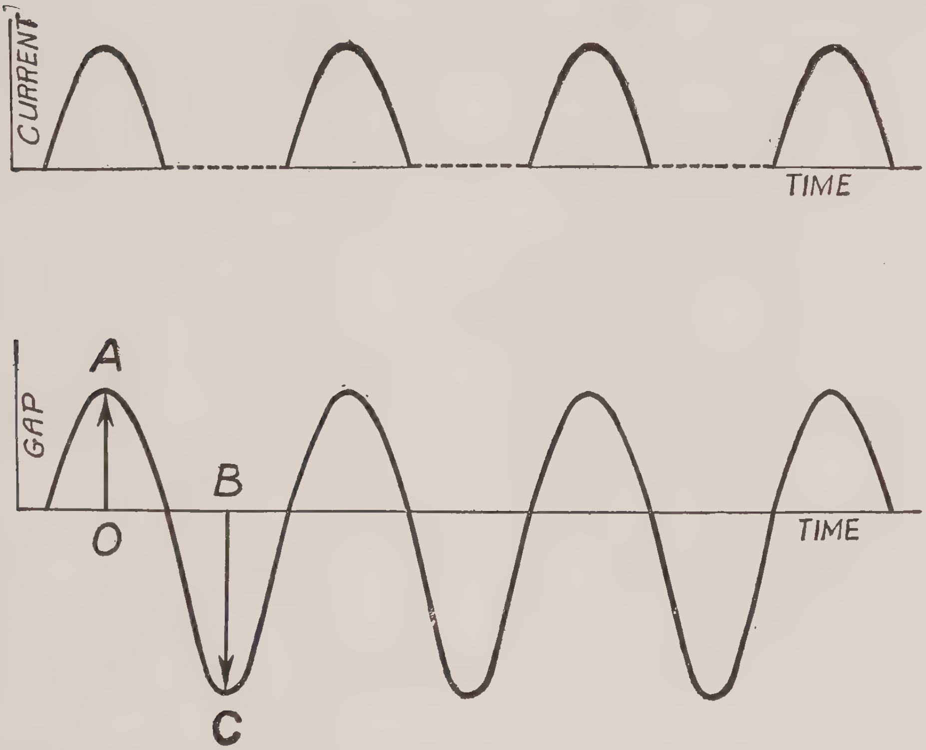


FIG. 9. Current and voltage curve for self-rectifying Coolidge tube. The voltage difference indicated by the excess of *BC* over *OA* will depend on design of transformer and control.

voltage too much from no current to that needed to operate it properly, since the voltage of the suppressed wave is quite decidedly higher than that of the one used, thereby causing spark-over and giving an incorrect idea of the actual working voltage.

The value of this arrangement for field work can hardly be overestimated, as there is no heavy and complicated rectifier. Operated from a small gas engine-driven gen-

erator, it is ideal for fluoroscopic work and satisfactory for emergency radiography. See U. S. Army Portable Unit, page 167.

Tube Focus.—The x-rays cannot be focussed by any known method, so that the terms focal point, etc., are misleading. *Electrons* can be directed by suitable cathode construction so that the greater portion strike a small area on the target. The diameter of this area is known as the "focus," and it is customary to speak of broad, medium, and fine foci. One can hardly state precise limits between these designations, but anything below 3 mm. would be extra fine focus; 3 to 4 mm. fine focus; 4 to 7 mm. medium focus; and over 7 mm. broad focus.

The size of focus is found by the use of a pin-hole camera, and should be given by the maker. Its size is important in two ways: First, in relation to the sharpness of image on plate or screen; second, as fixing the power that may be used without damage to the target. When an electron stream is maintained at high velocity against the target, there is a rapid rise in temperature which may result in vaporization or fusion of the metal. The rate of removal of heat by conduction is increased by broadening the focal spot, and the amount of metal suffering extreme rise in temperature is increased, so that for two reasons there is less danger of target damage.

The effect on sharpness of image is shown by using an exaggerated diagram as in Fig. 10. F_1 F_2 are the boundaries of the focal spot and 1-2 is the object. With the plate in plane A, had the only source been a point, F_1, a sharp shadow PQ would result; had F_2 been the only source, then RS would result. The only portion entirely shaded is RQ, and if the object is round, we have a central white spot with a variable shading out to a diameter PS. If the focal spot were very wide and the object very

small a plane *B* could be found beyond which there would be no white image.

The ring *PR* and *QS* is narrower the closer the object to the plate, the smaller the focal spot and the greater the target-plate distance. The apparent size of the shadow will vary somewhat with exposure, as regions partly shaded may be under-exposed when the exposure is brief and the true shadow may not appear at all.

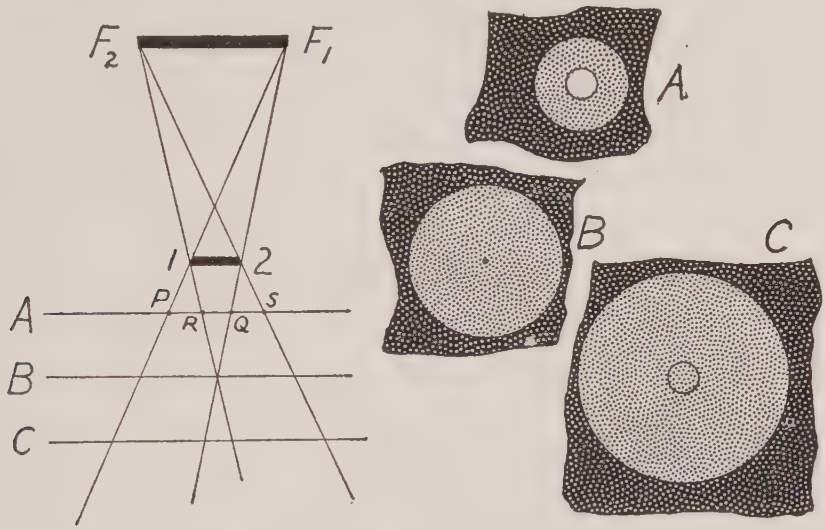


FIG. 10. Variation of size of shadows of small objects when a wide focus is used close to the plate.

Fine focus tubes are not needed in gastro-intestinal work, and should be used in other work with such care that the target does not become pitted.

Conditions for Operation.—Two things must be considered in the operation of x-ray tubes. The first is a proper supply of electrons as current carriers, the second a proper electric drive to force these electrons against the target. These two must be so related to each other that a proper voltage can be maintained when current is actually used.

No amount of milliamperage will serve to do radiographic or fluoroscopic work without a proper voltage consumption

at the tube. The potential difference or voltage drop across the tube is due to a piling up of positive charges and electrons at the target and cathode respectively and this must be done by the *generator.* When electrons move across from cathode to target they tend to relieve the congestion and, if the generator should fail to maintain the supply, the voltage and charge would disappear. The greater the number of electrons passing across in a given time, the more the terminal voltage will be reduced for a given ability of the generator to pump a new supply. The current is the charge of one electron multiplied by the number passing per second. Hence the greater the milliamperage, the greater the power demanded from the generator to maintain voltage and the more the drop in voltage from that shown on open circuit or on small current.

When the current increases, irrespective of the type of tube used or the design of the machine, the operating voltage will be reduced unless the rheostat or autotransformer control is moved to apply more power to the primary. *The spark gap on open circuit is no guide to the ability of the transformer or induction coil to keep up voltage when current is drawn.*

Inasmuch as reduced voltage very much more than offsets the effect of change of current in x-ray production as regards quantity, and likewise decreases the ability to pass through material, the proper maintenance of voltage is the most indispensable requisite in any x-ray installation. *By increasing exposure time nearly all work may be properly done at low current, but no increase of exposure time will compensate for too low voltage.*

The transformer must be designed for the voltage supply on which it is used, and it is very essential that the proper terminal voltage on the transformer primary should be maintained at all times and at all loads. After a machine

is once installed the operator has no control over these matters. The size of wire required to transmit current from the usual power transformer to the x-ray room will depend on the distance between the two transformers and on the voltage used. To transmit the same power at 110 volts as at 220 will require twice the current. Whenever a given current is passed over a resistance there is a voltage drop or loss. This loss is greater, the greater the current and the greater the resistance. When the line resistance and the current are known the voltage loss is found by taking their product. A loss of 2 or 3 per cent of the line voltage may be permissible. See line wiring, p. 70.

The operator must take care that the current through the tube does not drop the potential too much for the work required. For increased tube current the rheostat or autotransformer setting must be raised accordingly.

Gas Tube Characteristics.—The earlier type of tube depended for its supply of electrons on the breakdown of the atoms of its gaseous atmosphere, whereby the electrons and the positive remainder of the atom were separated and driven in opposite directions. This breakdown or ionization may be due to several causes:

1. The high electric stress between cathode and target.
2. The shooting of electrons through the atmosphere.
3. The passage of x-rays through the atmosphere.

The number of electrons set free will depend on the tube vacuum. If too few can be had, the tube is of too high vacuum and is called "hard." It backs up a very high spark gap, and may become "cranky." If too much gas is present the tube carries so much current that it is quite impossible to keep up voltage. The amount of free gas in the tube will increase as the parts of the tube rise in temperature, since gas tends to stick to a cold

surface. Therein often lies the explanation of failure in radiography on prolonged exposure.

The rate of softening of a gas tube operated at a given initial current and voltage varies with its original exhaustion and its use afterward. On low power with small current and high voltage there is a marked tendency to *reduce* the amount of free gas and thus raise the vacuum. When this tendency is just balanced by the evolution or release of gas by heat the tube runs at a nearly uniform current and voltage. On slightly higher power it will soften and the rate of softening will generally be greater with a new tube than in case of a well-seasoned one.

Danger in Testing.—It is unwise to test a gas tube at the power used in gastro-intestinal or other heavy work, as it is likely to over-soften before a milliammeter can be read or spark gap really ascertained. The usual recourse is to note current and gap at low power, and assume that when this is properly adjusted on, say, button *X*, it will give a proper result on a higher button *Y*. Careful study of these tubes shows that this is only approximately the case, for not only will tubes vary one from another, but the same tube will behave differently on different days. No better method has been suggested, however, so the operator should endeavor to season a tube, if possible, before attempting fast work.

Coolidge Tube Characteristics.—The electron supply in the Coolidge type of hot cathode tube is due entirely to the hot tungsten filament, as all the gas it is possible to remove has been taken out in pumping. The current carried by the tube is limited by the rate of electron supply and is thus determined solely by the filament current. This maximum *tube* current at a given *filament* current is only attained at a sufficiently high voltage and this voltage *increases* as the filament temperature is raised. When all

the electrons are being driven across as fast as they are produced, the corresponding current is named the *saturation* current. After such a current is reached the voltage may be greatly increased without a rise in tube current. Fig. 11 shows this characteristic of the tube, quite different from the gas-containing tube where higher applied voltage

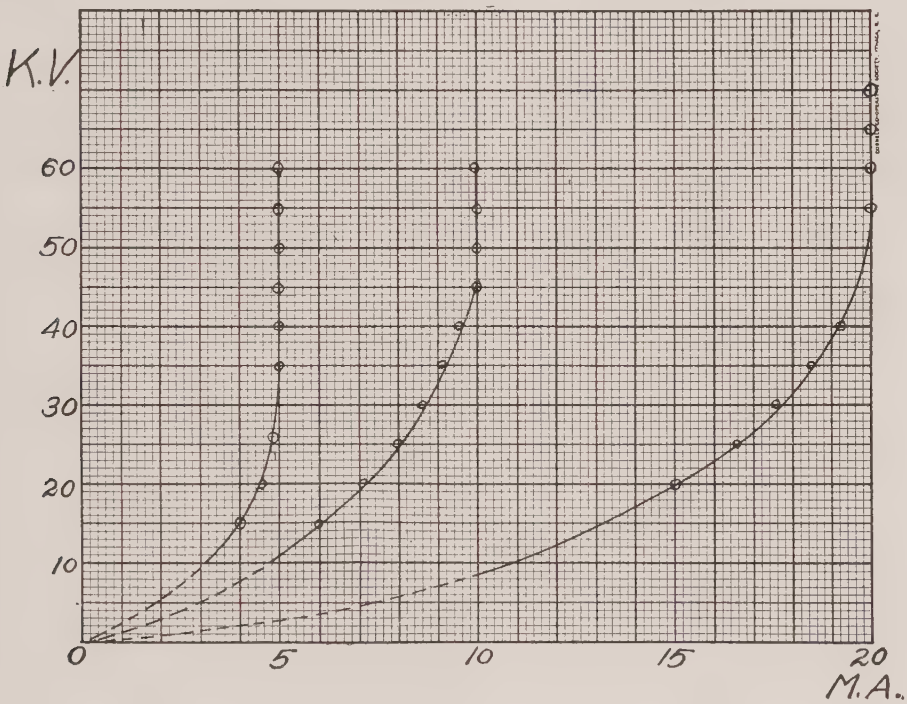


Fig. 11. Current-voltage lines of Coolidge tube for fixed filament temperatures. Vertical portions are above "saturation" points.

brings increased current. On account of the *great* increase of tube current resulting from a *slight* rise in filament current the writer has found it impractical to depend on the filament ammeter as a guide to tube current, especially when using rheostat control. In fact better work is done where no dependence is put on anything except spark gap and *tube* current.

Outflow of Radiation.—As radiation proceeds from the origin on the target it spreads out and flows through the

surfaces of larger and larger spheres. The amount received in a given time by any *fixed* area then decreases as the distance of the receiving surface is greater. This decrease always follows the *inverse square* law. Thus if 100 arbitrary units reach a given area at 10 inches from the target, the *same area* 20 inches from the target will only get ¼ as much in the same time, i. e., 25 units. At 30 inches the *same area* receives but 1/9 as much or 11 1/9 units. Or to get the *same* radiation to this area at the increased distances the time must increase as the *square* of the *distance*, i. e., if at 15 inches 2 seconds are required, at 20 inches $2 \times \left(\frac{20}{15}\right)^2 = 2 \times \frac{16}{9}$, at 25 inches $2 \times \frac{25}{9}$, at 30 inches $2 \times \left(\frac{30}{15}\right)^2 = 2 \times 4 = 8$ seconds, etc.

Amount of Radiation.—The measurement of x-ray radiation has proved a rather difficult matter and need not be fully discussed here. For our purpose the photographic measure is sufficiently accurate and determines the usefulness of the rays in practice. Whatever the conditions of operation, we might take a time of exposure so as to get the same blackening on two spots on a photographic plate, and then say that the two *had the same exposure,* when exposure does not mean time of tube action alone.

Such a method measures only the effect of rays used in changing the emulsion, *not* the total beam, the greater portion of which passes through the film.

Quality.—Fully as important as the amount of radiation is the quality or distribution of radiation among various wave lengths. Quality determines the ability of the rays to pass through flesh and bone, and was roughly gauged by the use of penetrometers. It depends on the voltage used to drive the current across the space between cathode

and anode, and is best expressed in terms of voltage or gap.

Dependence of Quantity on Electrical Conditions.—It is very important to realize that the amount of radiation as measured by the photographic effect is simply related to the electrical conditions under which a tube is operated.

If we let I = Current in milliamperes
V = Effective voltage in kv.

Then radiation leaves the target at a rate depending on the product of current and the *square* of the voltage. The amount reaching a given area placed at right angles to the flow and at a distance d from the target and in a time t is measured by $\frac{I\ V^2\ t}{d^2}$

Thus if $I_1 = 40$ ma., $V_1 = 30$ kv., $d = 20$ inches, $t =$ 1 second, in one case, and

$I_2 = 10$ ma., $V_2 = 60$ kv., $d = 20$ inches, $t = 1$ second in another, then Q_1 = 40x30x30x 1/400 = 90 arbitrary units where Q_1 = amount of radiation in the first case and Q_2 = 10x60x60x1/400 = 90 units in the second case. That is, 40 ma. at 30 kv. and 10 ma. at 60 kv. will produce the same quantity of x-rays as measured by photographic effect.

However, the radiation produced at 60 kv. is better able to penetrate any piece of matter, and a higher percentage passes through, so that a plate exposed partly to one and partly to the other through a block of material will show much more darkening for the second case, even though the quantities of radiation generated at the tube are equal. It would darken the plate equally if no body were interposed.

No matter what amount of current is passed through a tube it is useless for radiographic or fluoroscopic work, unless a voltage able to break down from 2 to 6 inches

of air between blunt points is used. For thick parts the higher voltage (gap) must be used.

The relation of sparking distance (between blunt points) to kilovolts is shown in Fig. 12. The kilovoltage is approximately ten times the gap in inches plus ten.

Penetration.—The most characteristic feature of x-rays

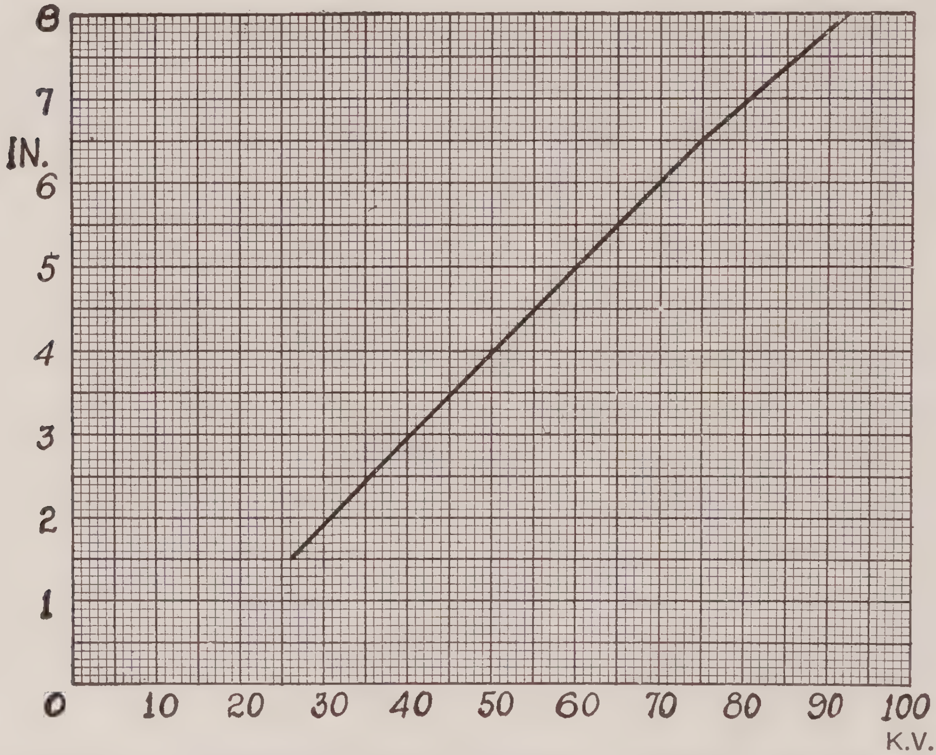


FIG. 12. Approximate relation between effective kilovolts and spark gap for moderately blunt points.

is their ability to pass through material quite opaque to other types of radiation. In all cases there is some absorption, but the rate of absorption or the amount left after passing through any layer of material varies according to the composition of the x-ray beam. The most penetrating rays are produced only at higher voltages. This penetration could be accurately defined in the case of a beam of one wave length, but it is quite difficult in the case of an actual complex beam.

It is essential for the operator to realize that increasing the tube voltage will (a) add shorter and more penetrating rays; (b) increase the quantity of the less penetrating which were produced at the lower voltage.

X-Ray Transformer.—There is no practical means of directly generating an electric current at the voltage needed in the production of useful x-rays, hence it is necessary to use a transformer, stepping up low voltage current to the high voltage required. The transformer consists of two coils of wire around a common iron core. For complete insulation of the coils from each other the system is immersed in oil or in wax. If in the latter, it is shipped complete; when oil insulated, the oil is usually shipped separately. In this case, it should be siphoned into the transformer; the inlet side should be raised an inch or so to get complete expulsion of the air. It is well to operate at a low power, allowing sparks to pass across an inch gap for some time to dislodge small air bubbles before putting it into service.

Use no oil not furnished for the purpose by a reliable manufacturer; *the oil must contain no moisture.*

Examine the oil level every two months to be sure it fills the tank. An exposed coil is sure to break down by puncture of the insulation. The top of the case should be kept free from oil and dirt. For protection against surges or sudden high tension pulses which are likely to damage the transformer, a resistance should be placed in shunt with the low tension terminals. If this is not provided by the maker, ordinary lamps may be used. Fig. 13.

The middle of the secondary is usually connected to the case (grounded); this insures a distribution of potential equally above and below the "earth" potential. Thus, if the terminal voltage is 40,000 volts, then the tendency to

pass a spark to any grounded conductor is 20,000 volts. This arrangement avoids in some measure the tendency to discharge to patient, stand, and tube that would result if the full terminal voltage were effective to earth.

Care must be taken to keep all contacts on the low voltage side tight. See that low tension wires are kept as far away from the high tension terminals as possible. If trouble actually occurs, due to short circuit or break inside

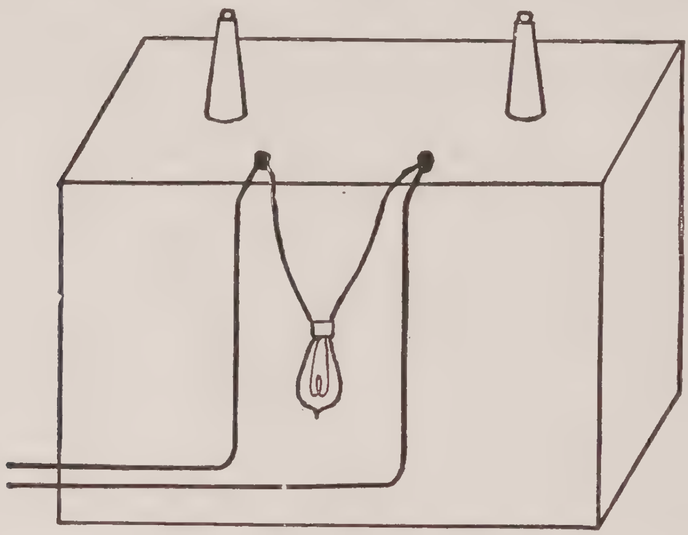


FIG. 13. Protection from surge by use of a lamp.

the transformer, there is no use in trying to repair it, as a rule, unless the trouble is close to the terminals. If there is trouble arising from sparking across between the high tension terminals of the transformer, attaching small spheres will relieve the tension and usually cure the trouble, or insulating barrier plates may be used.

Control of the Transformer.—Corresponding to each of the various high tension voltages maintained at the tube terminals, there must be applied a definite voltage across the primary of the transformer. The transformer changes voltage approximately in the ratio of number of turns in the primary to number of turns in the secondary, and

changes current in the inverse ratio. Thus a particular x-ray transformer might be wound with 500 turns in the secondary for each turn of primary, and it would be said to have a step-up ratio of 500. The secondary voltage would be 500 times the voltage in the primary and the secondary current 1/500 of that in the primary.

A table of the voltages that must be supplied and maintained at the primary terminals to give various high tension voltages can easily be made in this case.

Primary Applied Voltage	Resultant H. T. Voltage	Spark Gap (approximate)
80 v.	40 kv.	3 in.
90	45	3½
100	50	4
110	55	4½
120	60	5
130	65	5½
140	70	6
150	75	6½
160	80	7
220	110	10

Such primary voltages can be secured from a line supply of 220 volts (a) by the use of a rheostat, (b) by the use of an autotransformer.

Rheostat.—The rheostat is an adjustable resistance used to consume a part of the line voltage and leave the proper voltage to be applied at the transformer. Suppose, for instance, it is desired to have 40 ma., at a 5-inch gap delivered to the tube. The *primary* must be supplied with 120 volts and a current of 40 ma. x 500 = 20 amperes. In this case the rheostat must consume 100 volts from the 220 volt line with a 20 ampere current, Fig. 14. By

Ohms law ($V = IR$) the voltage consumed in the flow of current through a resistance is equal to the product of the current in amperes and the resistance in ohms. Therefore, $100\ v = 20 \times R$ from which $R = 5$ ohms, hence we would need 5 ohms of the rheostat to get the setting desired.

The rheostat consists of coils of resistance wire connected end to end, one end of the series being permanently connected to one wire of the power line. Re-

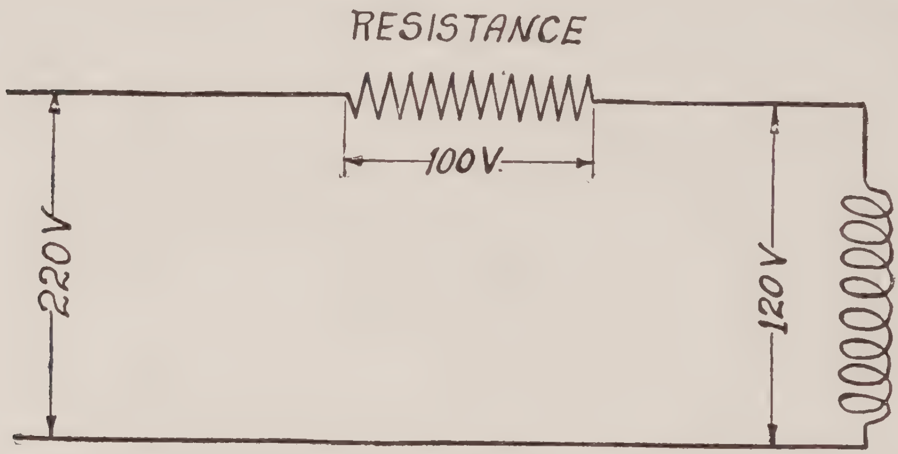


FIG. 14. Diagram showing consumption of voltage by primary of x-ray transformer and series resistance for a particular case.

sistance wire is made of some special material of considerably higher resistance for the same diameter and length than copper. An adjustable contact is used to join one transformer terminal to any desired point of the rheostat so as to include the required amount of resistance in the circuit. Fig. 15 shows the essential parts of a rheostat.

The usual numbering makes the power increase as the control lever is moved over to higher numbers. A good rheostat should be of substantial construction, well ventilated, and of such current capacity as not to get overheated under any operating conditions. It should be so

graded as to give 30 to 70 ma. on a 4-inch to 7-inch gap for radiographic work and from 3 to 5 ma. on a 9 or 10-inch gap for treatment.

The use of a rheostat to control tube voltage has the disadvantage that slight variations in tube current result in serious changes in voltage. To see how different tube currents cause such enormously different voltages on the same control setting, let us first construct a table to give the primary currents corresponding to different tube currents. Each primary current is 500 times the corresponding secondary.

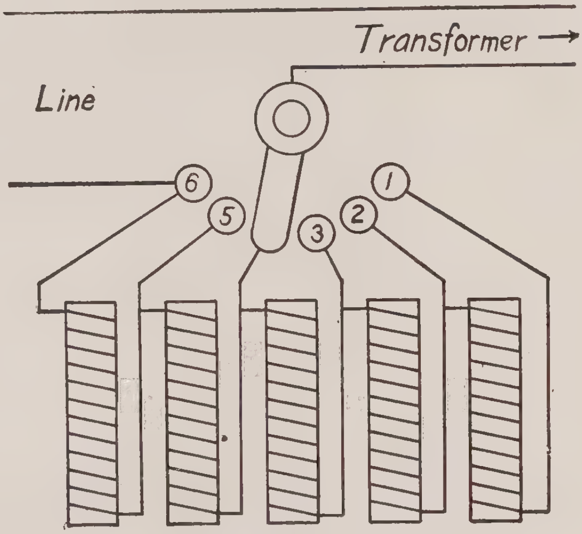


Fig. 15. Rheostat construction and connections.

Secondary Current	Primary Current
0 ma.	0 amps.
10	5
20	10
40	20
60	30
80	40
100	50

Assuming the setting of 5 ohms resistance, let us see how the voltage applied at the transformer varies under different loads. The voltage consumed in the rheostat is $V = I R$, where I is primary current and R is constant at 5 ohms.

Secondary Current	Primary Current	Voltage Consumed in Rheostat	Voltage left over to apply at primary	Resulting secondary voltage
0 ma.	0 amp.	0 v.	220 v.	110 kv.
10	5	25	195	97
20	10	50	170	85
40	20	100	120	60
60	30	150	70	35
80	40	200	20	10
100	50	250	—	—

These figures are represented graphically in Fig. 16. This results in the theoretical chart line corresponding to operation on the particular rheostat control button selected. For simplicity, no account has been taken in these figures of line wire resistance, resistance in the windings of the transformer, "magnetic leakage," and other factors which enter to a greater or less degree.

The voltage "regulation" under various loads of a rheostat controlled transformer is poor. On any one control setting the voltage will fall off very rapidly with an increase in current, and rise rapidly with a decrease. In Fig. 16 at 60 kv. and 40 ma. an increase of 8 ma., due to softening of a gas tube during exposure or to fluctuation in the filament temperature of a Coolidge tube, will lower the voltage 10 kv., or about an inch of spark gap. The loss in voltage and penetration will have considerably more influence on a plate than the increase in current. Also, if there were a break in the Coolidge filament line, or polarity were wrong, so that no current flowed in the secondary circuit the primary voltage would rise to that of the line with considerable likelihood of sparking to the patient or causing damage to apparatus.

Auto Transformer.—To secure better voltage main-

tenance under varying loads an autotransformer is often used. It consists of a continuous coil of wire wound around an iron core with taps taken out to control buttons at proper intervals, as shown in Fig. 17. If alternating cur-

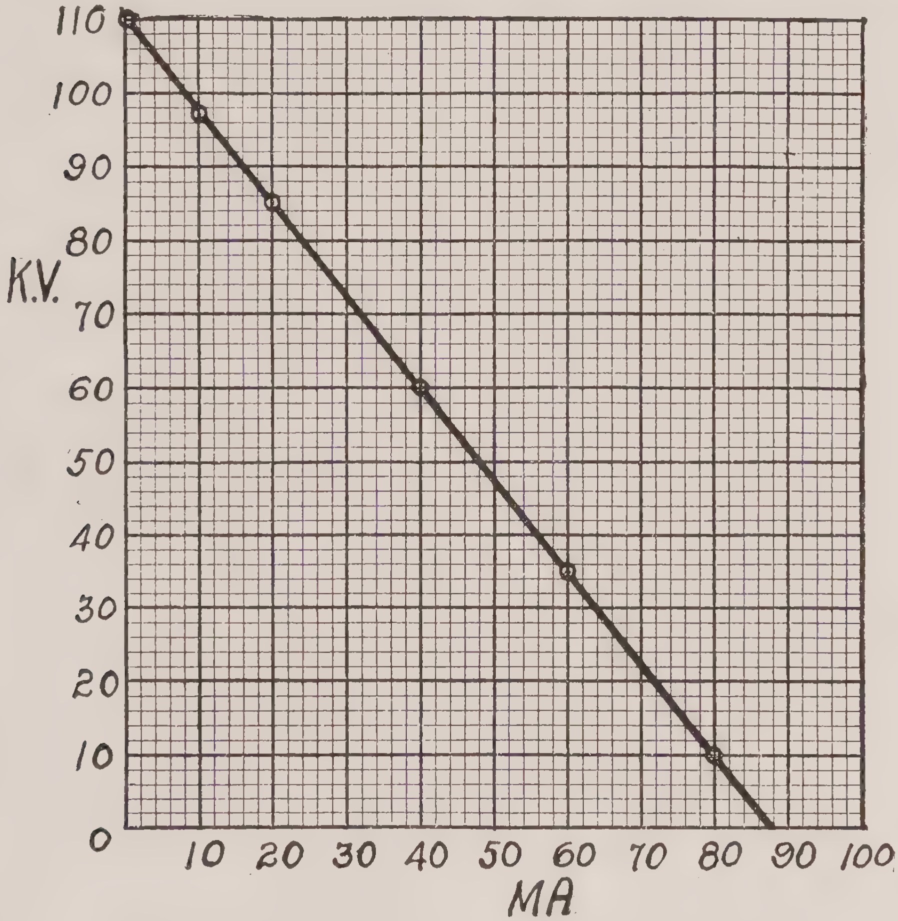


FIG. 16. Theoretical chart line plotted from data given in table on page 52. This line shows, for the particular machine and setting, the voltage at which various currents will be delivered.

rent be applied to the complete winding of such a coil there will be a voltage induced in any part of the winding, bearing the same relation to the applied voltage that the number of turns of this part of the winding bears to the number of turns in the whole coil. It is essentially the same as any other transformer, except that primary and secondary

are part of the same continuous wire rather than separate windings, and its action depends on self-induction in a single coil rather than on mutual induction between two coils. The ratio between the number of turns in the primary and secondary circuits is changed by setting the control lever

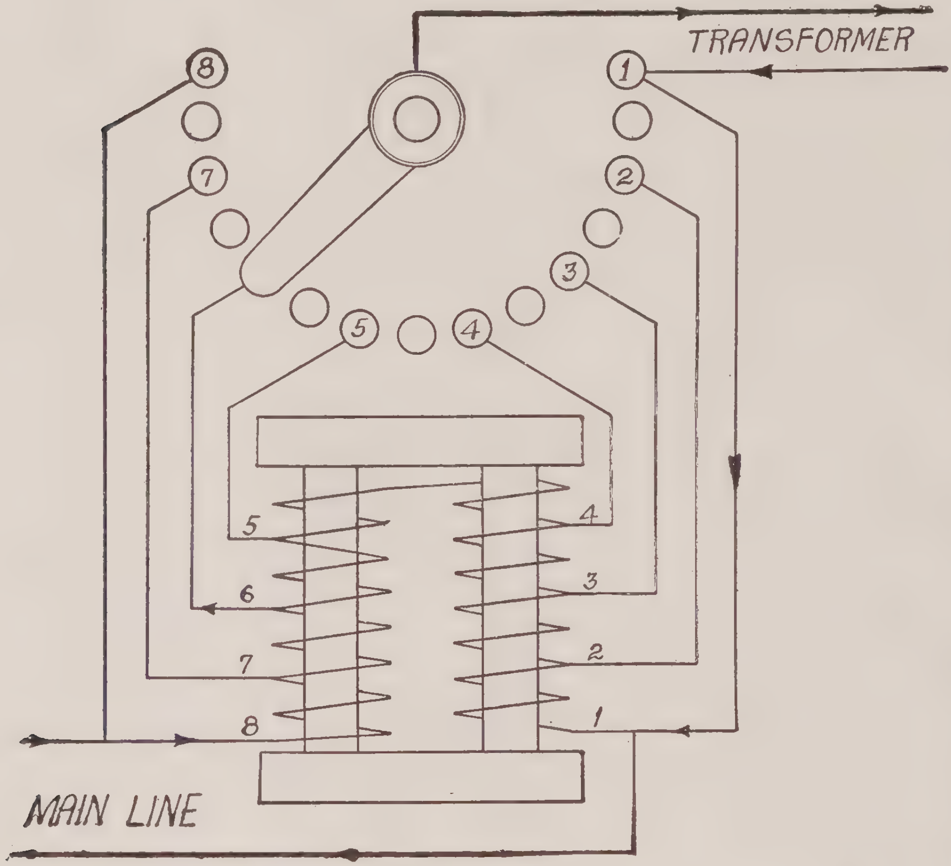


FIG. 17. Wiring diagram of autotransformer. Notice dead buttons between the active ones which are numbered.

on the various buttons. The autotransformer is used as a control device to reduce the line voltage to that which is applied to the x-ray transformer primary, hence it is a step-down transformer and has fewer turns in the secondary circuit than in the primary. As the control handle is moved to higher readings, more turns are cut into the secondary circuit and higher voltage is applied to the

primary of the x-ray transformer. Blank or "dead" buttons are placed between adjacent live buttons, which differ from each other by a few volts, to prevent a short circuit of this low voltage by the control lever being in contact with two live buttons at one time.

The autotransformer is more suitable than a variable ratio step-down transformer, which might be used, since it saves wire and iron, being much smaller for equivalent capacity, and therefore cheaper to build. The autotransformer principle cannot be applied to x-ray and filament transformers because their ratio is too large and the primary and secondary must be insulated from each other.

The autotransformer, like an ordinary transformer, is very efficient and does not change electric energy into heat like the rheostat. The windings are of large copper wire, with low ohmic resistance. When increased current is demanded from an autotransformer, it simply draws more current from the supply line and delivers the current demanded with very little drop in voltage.

When increased current is demanded in the tube, it will be supplied by an autotransformer with far less voltage drop than is the case with the rheostat. Fig. 18 shows the behavior of the two devices on a particular machine. Starting at 10 ma. and 60 kv., and raising the tube current on a fixed rheostat setting, gives the series of currents and voltages shown by the line AC; while on a fixed autotransformer setting we have the line AB. Since the quantity of radiation (measured photographically) increases as the current and the square of the voltage, we may compute the *relative* amount of radiation regardless of penetration. Curve DE shows the rheostat delivery down as low as useful rays are produced; DF shows the delivery on the autotransformer up to 60 ma.

This form of control is of special value when the fila-

ment current of a Coolidge tube is not entirely steady. Thus, if the tube current in the case cited changed from 10 to 15 ma., with a rheostat control, the radiation would be reduced in quantity from 32 to 25 arbitrary units and also would be much less penetrating; while with the auto-transformer the same change would result in an *increase*

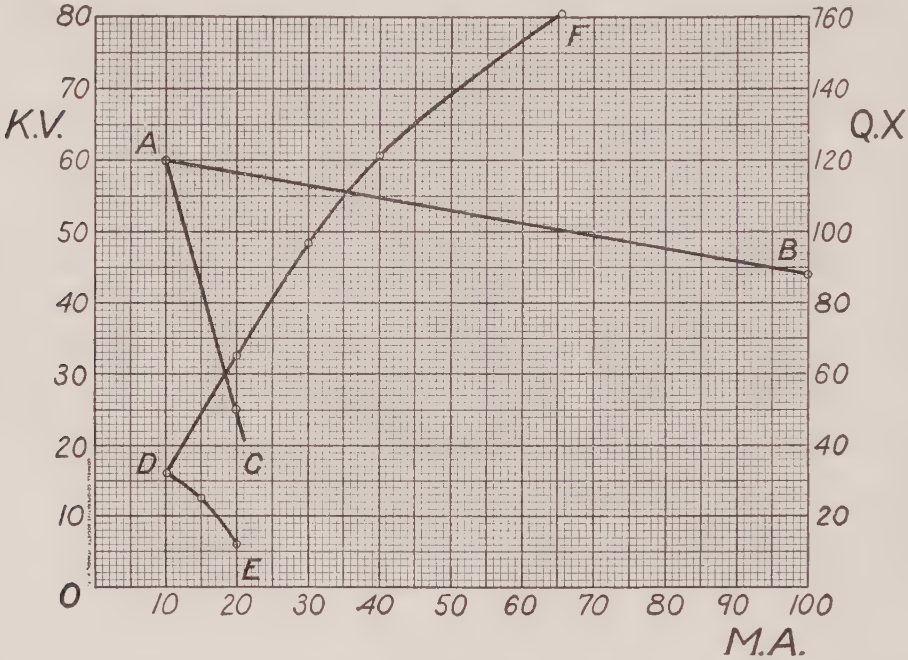


FIG. 18. Relation of x-ray production on two types of control. On rheostat control we have *AC* as the voltage-current line. Voltage ordinates at the left. *DE*, corresponding x-radiation quantity, ordinates at the right. *AB*, autotransformer chart line. *DF*, corresponding quantity line. Quantity in arbitrary units.

in quantity from 32 to 50 units very slightly less penetrating than at 10 ma.

"Inductance" Taps.—Instead of controlling completely by variation in the applied voltage, in some instances the winding ratio of the x-ray transformer is variable by a dial switch which cuts in more or less turns of the transformer primary. The lowest ratio of step-up corresponds to the complete primary and, since the secondary winding

is fixed, to cut out turns of the primary will increase the step-up ratio and give higher secondary voltage. As usually applied, the machine has essentially a rheostat control, with rheostat rather than autotransformer characteristics, and usually more taps are made in the winding than serve a useful purpose.

The same principle is conveniently applied in transformers built to operate on either 220 or 110 volt mains, half as many primary turns being used for 110 volts as for 220. The bedside unit uses this principle for 110 volt a.c. and the lower voltage a.c. obtained from the rotary converter. In some instances the primary is wound in two sections which are connected in series for 220 volts and in parallel for 110 volts, in the latter case giving carrying capacity for the heavy primary currents as well as the higher step-up ratio.

Transformer Chart.—A proper procedure in handling machine and tube is indispensable. Such a method should be adopted as will

1. Save time and tubes.
2. Render reproduction of results possible.
3. Apply to all machines.
4. Require a minimum amount of instrument reading when operating.
5. Indicate the working range of the machine.

The working spark gap, with moderate sized blunt points for a gap, varies from about 3 inches to 6 inches, and currents vary from 5 to 100 milliamperes in fluoroscopic and radiographic work. Any possible combinations on the machine, giving settings outside these limits, are practically useless.

On any transformer outfit find first a 5 ma. 6-inch gap setting, then a 40 or 50 ma. 6-inch gap or an 80 ma. 4-inch gap setting. Study no settings outside these limits. In

Fig. 19 take rheostat setting G as an example. *Read the current through the tube when a 6-inch gap just fails to break* (25 ma.). Record your setting and the current. Leaving the x-ray transformer *control unchanged* find the tube current at which a 5-inch gap just fails to break. Do the same for a 4- and for a 3-inch gap. When these readings are plotted to scale, as in Fig. 19, they should

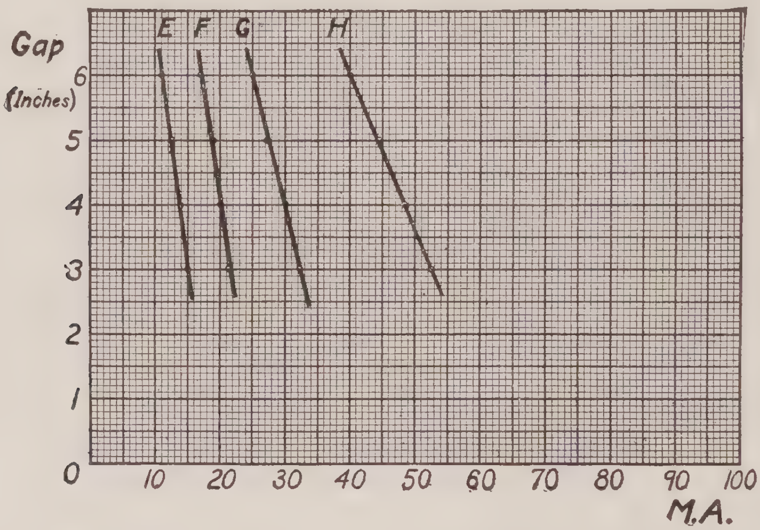


FIG. 19. Partial "chart" of a particular machine with rheostat control. Note that gap change, as tube current increases, is very rapid. On G, for example, we have a 6-inch gap at 25 ma. and only a 5-inch gap at 27.5 ma. or a change of an inch for each 2½ ma. Compare with Fig. 20.

fall nearly on a straight line. If they do not do so, repeat the observations.

So long as the power supply is kept at the voltage prevailing when this chart was determined the coördinates of a line give all the currents and voltages at any time available on the indicated rheostat setting. H gives the currents at which gaps between 6 and 3 inches are broken on button H. Fig. 20 shows five such lines for a particular machine on autotransformer control.

How to Use the Chart.—Using chart, Fig. 19, one needs

for a particular case 20 ma. at a 4-inch gap. The vertical line through 20 cuts the line marked *F* at the 4-inch gap. Hence we must use button *F*. Have spark gap open to seven or eight inches as a safety valve and forget it entirely. Move rheostat lever to *F*, look at your milliammeter, use one hand on transformer primary switch and the other on the Coolidge control. Close transformer switch and bring filament control to a setting, giving 20 milliam-

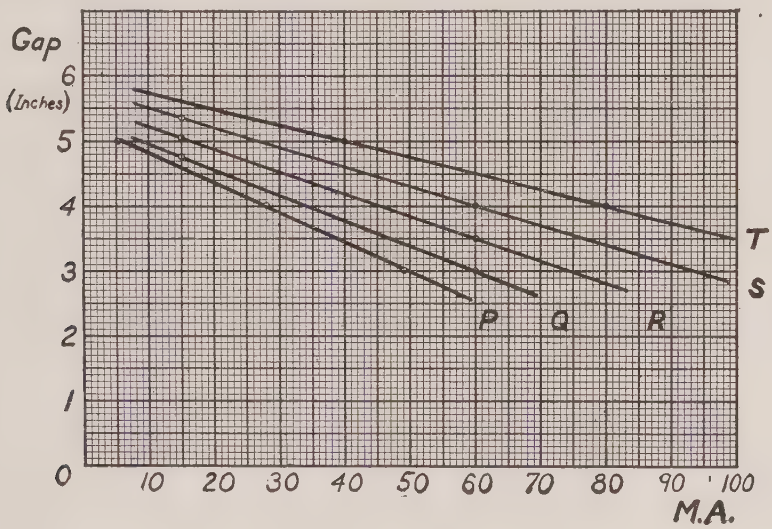


FIG. 20. Partial "chart" of the same transformer using autotransformer control. Note that line marked *P* shows all *useful* currents that can be had on this setting: changing from 5 ma. to 50 ma. lowers gap from 5 to 3 inches.

peres tube current; there is no need of testing the spark gap.

Do not try to read the milliammeter on the throw. Learn to start and set your machine within 10 seconds. On 20 ma. desired, a current of 19 or 21 ma. is close enough for this work.

Using chart, Fig. 20, for 45 ma. at a 4-inch gap, go at once to *R* and proceed as before. A little time spent in making this chart and in using it will reduce time lost and failures. Note that the faster the spark gap falls with

increase of tube current the more accurately must the filament current be adjusted and maintained.

Synchronous Motors.—A synchronous motor is one that makes either the same number of revolutions per minute as the generator feeding it or a fixed fraction thereof. Thus, if fed by a 60 cycle alternating current, there are 7200 alternations per minute. One alternation is produced whenever a conductor passes one pole piece of the generator. Thus, a 60 cycle current from an eight-pole machine requires 900 r.p.m (revolutions per minute), since 7200 = 8 x 900. For a four-pole machine we must have 1800 r.p.m., etc. A four-pole motor must then make 1800 r.p.m. for synchronism if on such a circuit, and it must not make 1801 or 1799. Since the rectifier for a 60 cycle current must make a quarter-turn each 1/120 of a second, the motor must turn at 1800 r.p.m. It must be observed that such a motor is designed for a given frequency and cannot be expected to work on one greatly different from that intended.

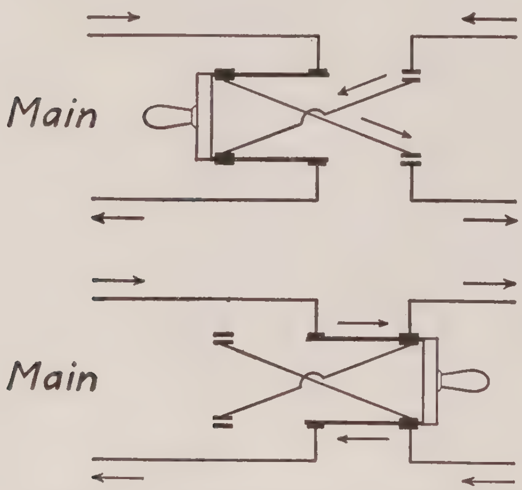


FIG. 21. Wiring of "polarity" switch.

Starting.—Many motors require connection to a special starting device in order to bring them up nearly to the required speed before making the running connection. Do not delay too long, and do not throw over the switch too quickly. A little practice will enable you to tell by the sound of the machine when the speed is about right.

Polarity Indicator.—Some machines have a field wind-

ing which ensures the same terminal polarity each time the machine is started. In most machines there is as much chance of a given terminal starting + as —. Polarity indicators are often used to show which way the rectifier comes into step. Either a primary reversing switch, Fig. 21, is used or the motor switch is opened for an instant and again closed, thus allowing the motor to drop back with

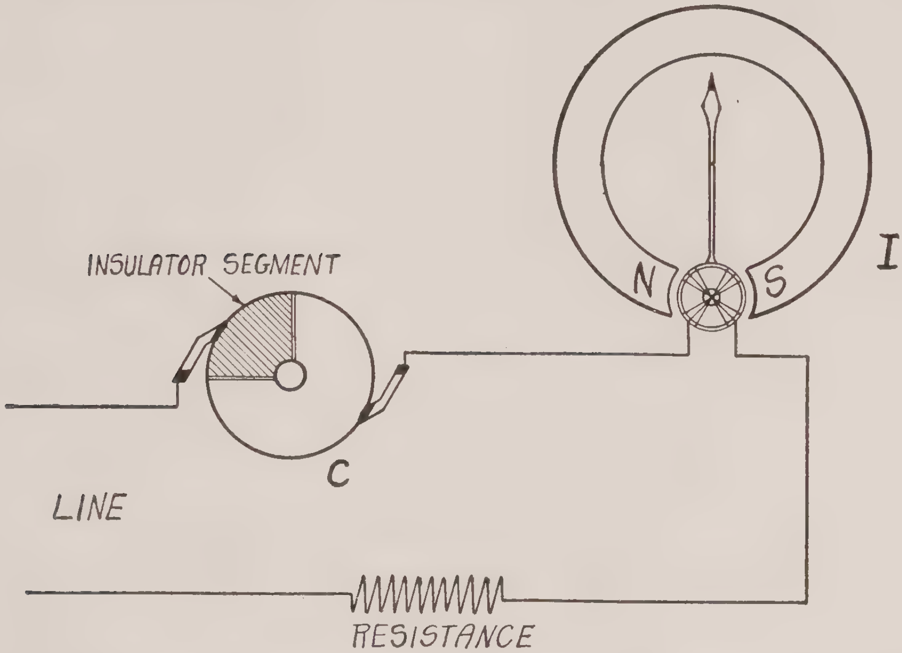


FIG. 22. Principle of polarity indicator. Note resistance in series.

the chance of changing polarity of the high tension lines. These indicators are devices to indicate direction of current flow, used in connection with a small low-tension rectifier driven by the motor. In Fig. 22 a source of alternating current is obtained from the primary lines; C is the low tension rectifier, or commutator, fastened on the same shaft as the high tension rectifier, and I is the indicator.

The direction of the rectified current through the indicator circuit will be one way or the other, depending on how the two rectifiers happen to come into step. The indi-

cator itself consists of a movable coil with pointer attached, working against a hair-spring in a permanent magnetic field, and it is very similar in construction to a direct current voltmeter or ammeter. If the rectified current flows one way through the coil, the needle will be deflected to on side; if the current flows in the reverse direction, the needle will swing to the opposite side.

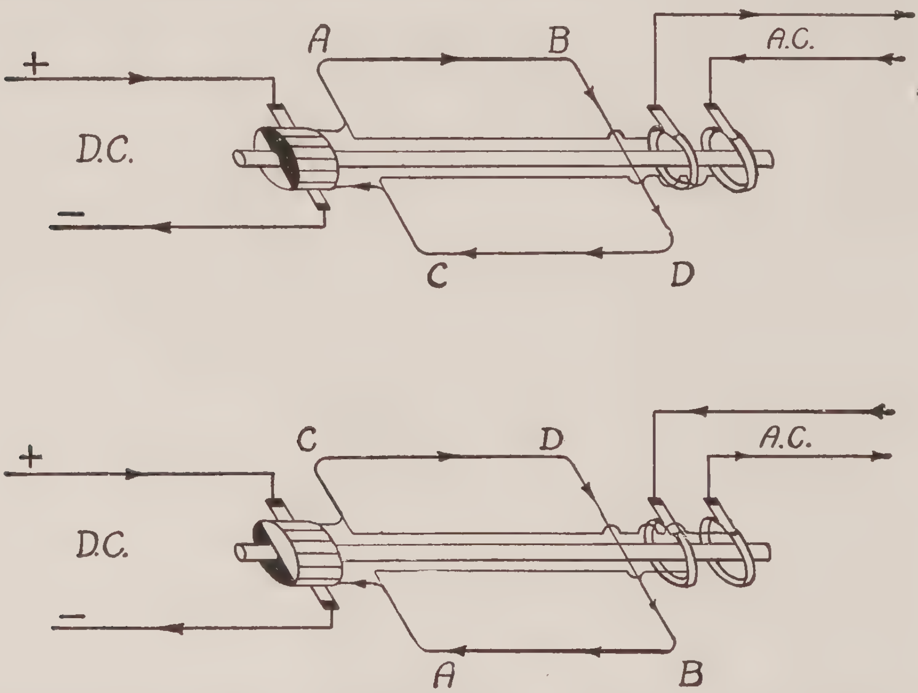


FIG. 23. Principle of rotary converter showing two positions of active coil 180° apart, armature current being always alternating.

The indicator is usually of low resistance with an auxiliary resistance unit included in the circuit to prevent burnout of the indicator coil. Never connect the indicator without this resistance in circuit, and in testing to find the proper connections always use a lamp in series with the indicator to prevent burnout, if connection is accidentally made to too high voltage.

Rotary Converter.—If the line supply is direct current it must be changed into alternating by means of a rotary

converter, since the x-ray transformer will operate only when its primary is supplied with alternating current. The operation of the converter is based on the fact that the current flowing through the armature of a direct-current motor is alternating. To simplify explanation, consider the case of a machine having two field poles and a single armature coil. At the left, Fig. 23, are the brushes to which the direct current line is connected, and at the right those from which the alternating current is drawn. The flow of current through the armature coil in the direction of the

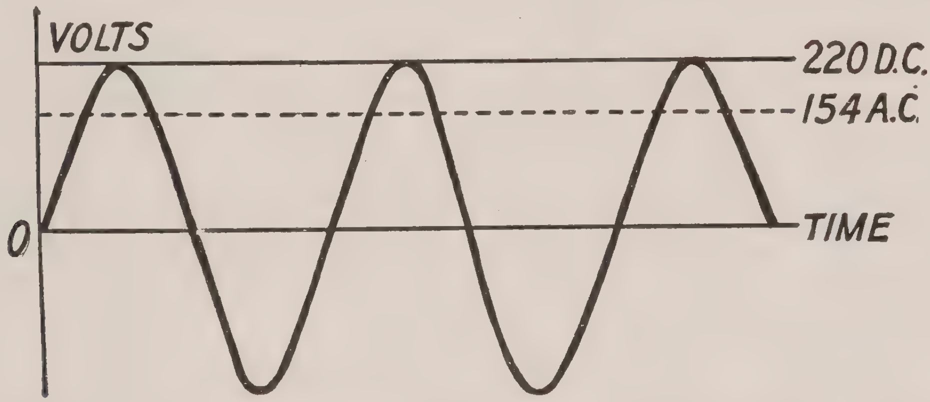


FIG. 24. Relation between d.c. voltage supplied and a.c. voltage delivered.

pointers causes rotation of the coil as indicated, owing to the reaction with the magnetic field between the stationary pole pieces. When the coil has rotated just beyond the vertical plane the connection of the rotating commutator segments with the d.-c. feed brushes is reversed, the current through the armature coil is reversed, and rotation is thereby made to continue. Each half revolution of the armature causes a reversal of current through the armature winding and a change in polarity of the two segments. If, now, these segments are continuously connected to the same collector brushes by means of slip rings, the current drawn from these brushes will be alternating current.

The direct-current voltage supplied to the rotary converter corresponds to the peak voltage of the alternating current wave, and the effective voltage of the alternating current is only about 70 per cent of this, Fig. 24. Thus a converter operating on 220 volts d.c. will deliver only 154 volts a.c. and if 220 volts a.c. are required, it is necessary to step up by means of a special transformer or autotransformer. Under heavy load the voltage will fall considerably below the 70 per cent, and serious difficulties will arise from trying to use a rotary converter too small for the demands placed upon it.

In direct-current x-ray machines the rotary converter drives the rectifying device. In this case, the machine always starts up with the same high tension polarity, and a polarity indicator or polarity switch is unnecessary. If polarity is wrong permanently, interchange the primary lead wires at the transformer or reverse the tube in the stand.

In using a rotary converter, one should remember that all the power used passes into the rotary through the d.-c. brushes, and all used by the x-ray transformer passes out from the slip rings. In the a.-c. machine the transformer power does not pass through the motor, so that greater care of brushes, etc., is needed in the d.-c. machine.

A considerable proportion of failures of rotaries is due to the breakdown of insulation at the connection of the armature wires to the slip rings. ''The Care of Motors'' on page 84 applies also to rotary converters. Protection should be made against high tension surges by connecting an incandescent lamp across the a.-c. end, as is done to protect a transformer, Fig. 13.

Rectifier.—Two forms of rotating circuit changers are in common use, the cross-arm type and disc type. Both are run by a synchronous motor, and they must be correctly

placed relative to the motor armature if efficient delivery is to be secured. Fig 25 shows the current path for the four-arm type, Fig. 26 for the two-arm, and Fig. 27 for the disc type.

In Fig. 25 when the right hand terminal of the transformer is –, the flow of negative charge or of electrons is from *A*-*B*-tube-*C*-*D*. If the spindle turns 90° while the polarity of the transformer is reversed, electrons flow from

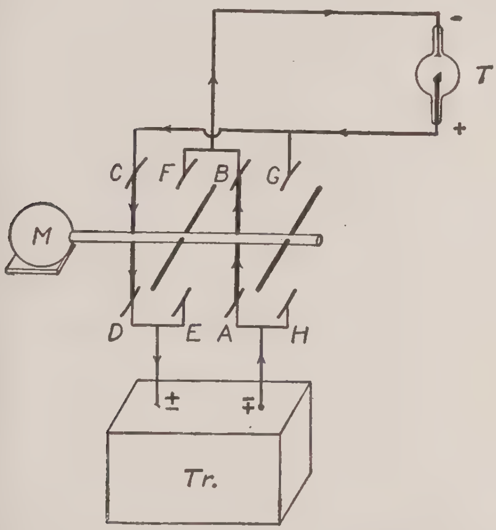


FIG. 25. Secondary circuit of Snook machine. Cross-bar type rectifier—four arms.

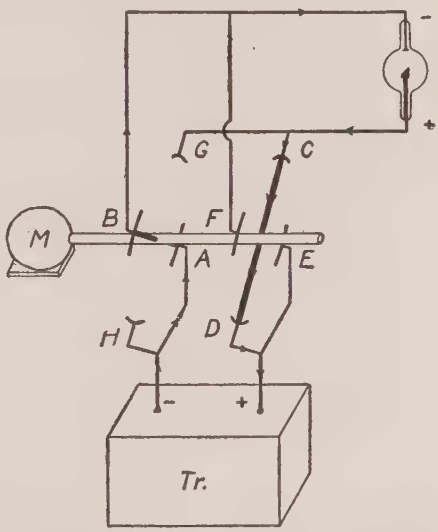


FIG. 26. Second circuit Waite & Bartlett machine—cross-arm type—two arms.

E-*F*-tube-*G*-*H*. In both cases the current takes the same direction *through* the tube.

The disc type is shown in Fig. 27. *PQ* and *RS* are two conducting sectors fastened to an insulating disc turned by the motor.

Flow is *A*-*B*-tube-*C*-*D* in one case and a quarter turn connects *D* to *B* and *C* to *A*. Meanwhile the transformer has reversed so that electrons pass from *D*-*B*-tube-*C*-*A*.

In Fig. 25 the cross-arm machine, *E* and *A*, *C* and *F*, *B* and *G* must be well insulated by barriers, or else the shaft must be unduly long. In the disc machine the diameter

must be large enough to insure insulation between the shaft and the rim and also to avoid establishing an arc between the fixed sectors along the edge of the disc.

Sparking Troubles.—Dust and moisture may impair the insulation of the barriers or disc. Keep them clean and wipe with a cloth *slightly* moistened with kerosene.

The cross-arm type must be well insulated where the arms pass through the shaft. If a break occurs there, it is not possible to patch it up. Get a new cross-arm.

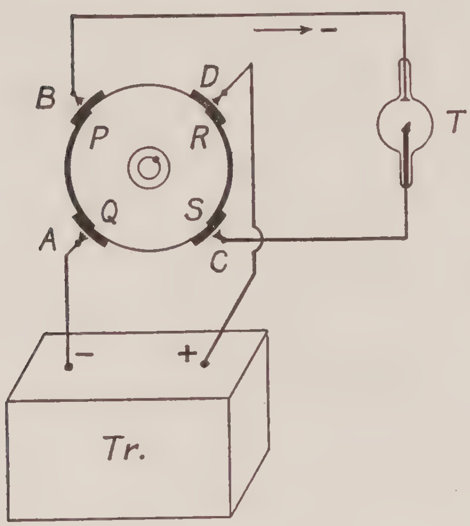


FIG. 27. Secondary circuit for disc type of rectifier.

Noise.—If a disc is out of balance or if the bearings are worn by lack of lubrication a machine will be noisy. Be sure to keep bearings w e l l oiled. Do not accept a machine poorly balanced.

Inverse.—Inverse shows by fluorescent rings back of the target in a gas tube and by sparks across gap on low power setting on Coolidge tube. It is caused by rectifier out of position. It is assumed that the maker will *mark* the shaft of the cross-arm type or the disc in the other class with reference to the motor shaft so that one can see if slip has taken place and adjust to the proper position. If this has not been done, readjust so that the current is a maximum on a low power setting and with the tube kept constant. This is fairly easy with a Coolidge tube. One accustomed to the appearance of the arcs at the rectifier terminals can set fairly accurately by observation.

Electro Magnet and Solenoid.—Surrounding a wire while it is carrying an electric current there is always a magnetic field which will deflect a compass needle placed near it into a position as shown in Fig. 28. If now the wire be wound into a coil the magnetic action formerly distributed along the length of the wire is concentrated in the center of the coil, and if a piece of iron be inserted as a core the intensity of the field will be still further increased since the iron is much more permeable to magnetism than air. The coil is a magnet only while current is actually flowing and its magnetic strength is greater the more turns of wire and the greater the current, and depends also on the dimensions and quality of the iron core and the design of the magnet as a whole. If the core is fixed and the magnetic action attracts an iron armature, as in some remote control switches, it is called simply an electro-magnet, whereas if the winding is hollow and by its magnetism sucks an iron plunger into the coil, as in the throttle control of the portable unit engine and certain remote control switches, it is called a solenoid. An

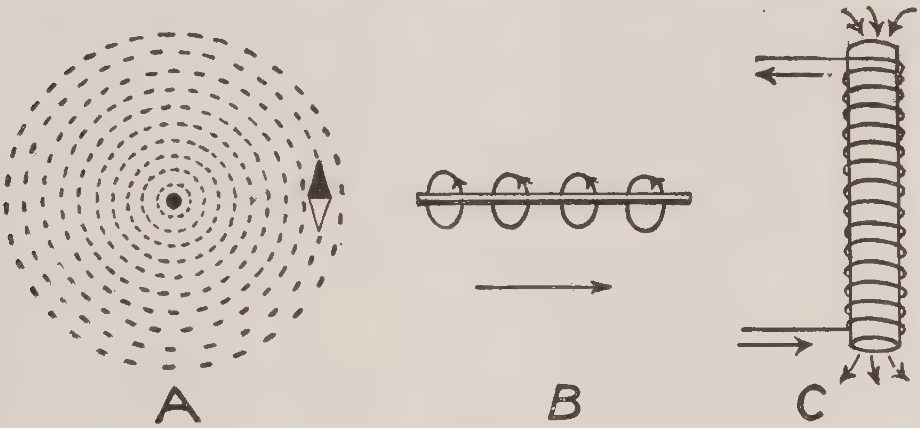


FIG. 28. Relation between an electric current and its resulting magnetic field. (a) Cross section of conductor with compass needle in field. (b) Straight portion of a conductor showing current and field. (c) Magnet coil with iron core. Greater strength than the same coil without iron core.

electro magnetic winding should never be connected on a voltage for which it was not designed, and a winding made for a.c. or d.c. must never be connected to the other type of current supply, as is explained in the next section.

Choke Coil.—If an alternating current be applied to an electro magnet there will be a choking effect due to the slow magnetizing of the core and the rapid alternation of the current. Less current will flow than if a corresponding voltage of direct current be applied, and the difference will depend on the properties of the magnet and the frequency of alternation. Never expect a magnet designed for d.c. to operate satisfactorily on a.c., for it will not let pass sufficient current; and *never* connect an a.-c. winding to d.-c. lines, since so much current will flow as to most likely burn out the coil immediately.

The choke coil is quite generally used instead of a rheostat as a means of control for the Coolidge filament transformer. Variation is secured by moving a piece of iron in or out of the field, the more iron in the field the more choking effect and the dimmer the filament, and the less iron the brighter the filament. Gradation of control is complete and there are no sliding contacts to cause trouble.

Protection against Surge.—The insulation of the apparatus in the primary circuit is sufficient for 220 volts, but not for high tension. If a sudden impulse or surge of electricity is set up in the primary circuit, due to a ground or short circuit of the secondary, or a spark back to the primary, the voltage in the circuit may amount to many times what it normally is.

Most of the apparatus in the primary circuit is inductively wound (electromagnetic coils with an iron core) and offers so much objection to the passage of a *sudden surge* that the path of least resistance may be through the insulation of the coils rather than through the com-

plete winding. When the insulation is punctured by the momentary pulse of high tension and a spark established, the low voltage is able to maintain this spark and build up a heavy arc, resulting in a burnout.

Protection against surges in the primary can be secured by connecting in shunt with the main transformer and motor a protective resistance, as shown in Fig. 13. This resistance is so high that it normally lets pass an insignificant amount of current, but in case of a surge the current will go through the resistance rather than break down the insulation, and the apparatus is protected.

The protective resistance may be in the form of a carbon rod, an open winding of fine resistance wire, a resistance wire baked into an enameled porcelain shell, or simplest of all, an ordinary incandescent lamp. If the more elaborate devices become broken and cannot be replaced, a lamp should be substituted rather than leave the equipment unprotected. If the lamps at hand are not of sufficient voltage, they can be connected in series; two 110-volt bulbs in series are equivalent to a 220-volt bulb.

Remote Control Switch.—Machines are frequently equipped with remote control switches or contactors which serve to make and break the heavy primary currents and to permit the use of a small, convenient operating switch. The operating push button or other device makes and breaks a small current in an auxiliary circuit, which is sufficient only to operate the magnetic switch. When the auxiliary circuit is closed, current passes through the magnet of the remote control switch and attracts an iron armature, thereby making contact and closing the main primary circuit. When the auxiliary circuit is opened the magnet ceases to attract the armature and a spring or gravity opens the contacts in the main primary.

The timing elements of most timers are delicate devices

and not able to make and break the heavy main primary current. They should be connected always in the auxiliary circuit of a remote control switch, where the current is light and will not cause damage, and they should never be inserted directly in the main primary circuit.

Line Wiring.—The line for x-ray installations should receive more careful attention than has usually been given to such important work.

The primary or low tension wiring should contain enough copper to insure that there will be no considerable voltage drop on the line even when the heaviest work is done. If a line from a supply transformer or a generator has a resistance of say .3 ohms, and one draws 50 amperes, a loss of .3 x 50 = 15 volts would result. If the original voltage was 100, the total available at the x-ray transformer would be 85 volts. On 220 volt operation this is not so serious, but more reliable operation will be attained if the wire is such that at the *highest* primary current the line drop does not exceed 3 per cent.

When a.-c. lines are used, the transformer from which power is drawn should be of ample capacity, and on d.c. the generator should have a capacity exceeding any estimated demand. Connecting a 10 kw. x-ray transformer to a 5 kw. line transformer is poor business. Fuses or circuit breakers should be conveniently placed, and all care should be exercised to avoid short circuiting or grounding the lines.

The following table shows the loss in voltage of a primary line for 50 and 100 amperes low tension current, on the assumption of a run of 100 feet between an x-ray transformer and the power transformer, giving 200 feet of line. The terminal voltage to be taken by primary and control is the difference between the line voltage and the loss. Thus, a machine drawing 100 amperes for a short exposure on a 220 volt circuit, using No. 10 wire, will have 220 —

19.9, or about 200 volts available. On 110 volt operation, 110 — 19.9 = 90 volts, making a very decided percentage drop. For this reason, machines using a large primary current are unsuited for 110 volt operation if rapid work is required.

No.	Ohms per ft.	Volts lost 200 ft. 50 Amp.	Volts lost 200 ft. 100 Amp.
00	.0000778	.778	1.5
0	.000098	.98	1.96
1	.000124	1.24	2.4
2	.000156	1.56	3.1
3	.000197	1.97	3.9
4	.000248	2.48	4.9
5	.000313	3.13	6.2
6	.000394	3.94	7.8
7	.000497	4.97	9.9
8	.000627	6.27	12.5
9	.000791	7.91	15.8
10	.000997	9.97	19.9

To compute the size of wire needed, one must know: (a) the maximum primary current in the x-ray transformer; (b) the distance from the supply transformer (or generator) to the x-ray transformer.

The *loss* in voltage due to line resistance is given by the product of *current in amperes by resistance in ohms of line wire per foot, by length of supply wires in feet.* Thus, on a 220 volt line, *if* a drop of 6 volts is permissible, the line being 200 feet long and the maximum current 60 amperes, then

$$60 \times 200 \times \text{Resistance per foot} = 6 \text{ volts}$$

$$\text{Resistance per foot} = \frac{6}{60 \times 200}, = .0005 \text{ ohms.}$$

The smallest permissible wire then is "No. 7." Better use a wire considerably larger to insure the best operation.

High Tension Wiring.—In the use of high power machines, much greater care should be taken in high tension construction than is generally the case. Three points should be carefully considered. These are: First, safety of the patient and operator; second, prevention of loss by leakage; third, avoidance of puncture of tubes.

While one might get a very unpleasant jolt from an induction coil, yet danger to life is slight as compared with transformers of like voltage. In general, a *maintained* voltage of 500 through vital portions of the body is dangerous if a current of 100 ma. or more can be delivered. A static machine, an induction coil, or a condenser may give a high initial voltage with a *brief* rush of current upon contact or grounding; this is disagreeable but usually harmless. In a power transformer which *maintains* voltage, the current continues, with possible fatal results. In most, if not all, installations the *middle* of the secondary coil of the transformer is connected to the iron case or to the "earth"; the earth is such a large reservoir that its electrical condition may be regarded as constant. The "ground" need not, and in fact should not, be completed by an actual metallic connection of transformer case to a water or gas pipe. Thus, when working at 60 kv. between the tube terminals, the voltage between the + line and the earth is + 30 kv., and between the — line to earth — 30 kv.

This divides the insulation strain on the transformer and reduces danger of sparking to the stand. If one terminal of the transformer were grounded, the full voltage would tend to pass current from the other line to anything connected to the earth. Thus, there would be a ten-

inch spark length to stand, floor, water, and gas pipes, etc. When treating at a ten-inch gap the strain is then double that in the other connection, but the line to the grounded side of the transformer is safe to touch. When using metal stands, tables, and protecting screens with the metal screens *between the tube* and the patient, they should be well grounded. The patient is then free from induced "static"

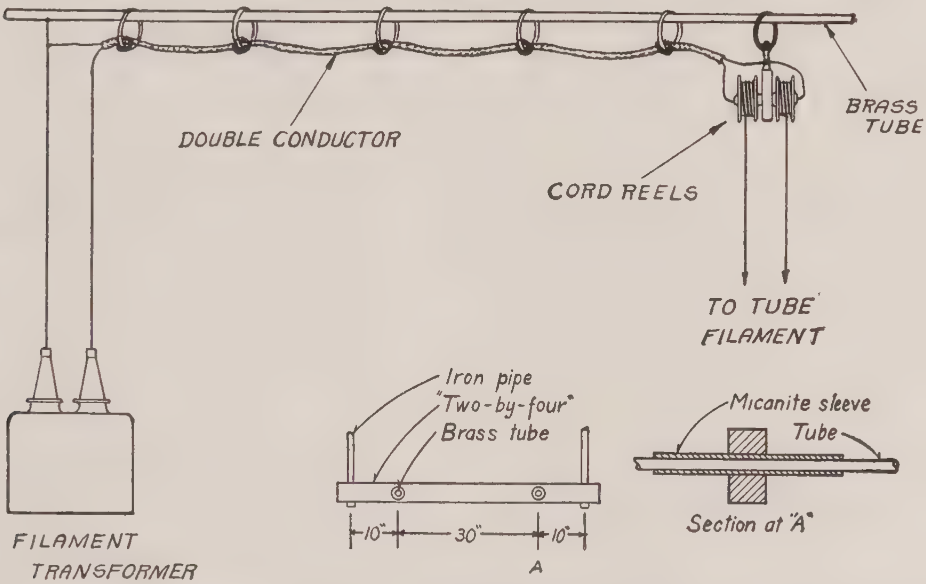


FIG. 29. Arrangement for constant resistance between filament transformer and Coolidge filament. Wire may be used instead of brass tube in the same way.

and from any discharge that may occur between the parts of the outfit. *When the patient is between the tube and the grounded metal, there is always more danger to the patient,* and corresponding care must be used.

Aside from the difficulty of preventing spark discharges and arcs, it is of great importance to prevent leakage between all parts having a high potential difference. This leakage is due to high electric stress, rendering the air conducting and giving rise to "corona." Also, many good insulators when clean and dry become conducting when

dusty and moist. High tension wires mounted on ordinary wood or on glass may be expected to leak badly.

Surface leakage is less on hard rubber and micanite than on glass. Wiping insulating surfaces with a cloth *slightly* moistened with kerosene will often greatly reduce leakage over the surface.

Corona loss is decreased by reducing the electric stress between the conductor and the surrounding air. This is accomplished by avoiding points, sharp edges, and close proximity of conductors of high potential difference. High potential overhead lines should be from 24 to 30 or more inches apart. All sharp points and corners should be avoided and small wires, especially if cloth insulated, should *not* be used. Gutta percha covered wire *without* braided covering is useful where a flexible conductor is needed. For rigid wiring and overhead lines, metal tubing not less than half inch external diameter should be used. This may be mounted by insulating rods attached to the ceiling, or as shown in Fig. 29.

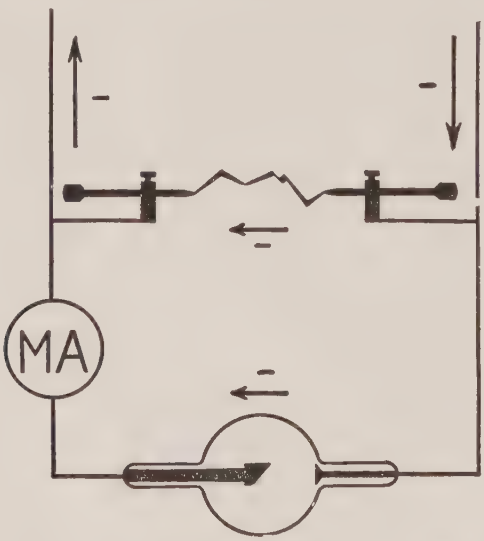


FIG. 30. The path of negative charge from line through spark gap, tube and milliammeter.

The same design can be easily adapted to inter-connecting rooms by mounting the tubing in the center of a large micanite or porcelain tube and filling the space with a good insulating wax. The insulating tube should be extended 6 to 8 inches from the wall. The rings for tube connection may carry reels if desired.

While line leakage of moderate amount may be tolerated in fluoroscopic or radiographic work, it may be of great importance in treatment. A milliammeter measures not alone the tube current but all leakage *beyond* the instrument itself. Corona between wires, spark gap corona and surface leakage together may give an error of two or three hundred per cent. We may avoid this (1) by proper design, (2) by *always* connecting the milliammeter beyond the spark gap as shown in Fig. 30. (3) Where any doubt arises check by testing with a second milliammeter connected directly to the tube.

Tracing Circuits.—The modern transformer x-ray machine is rarely characterized by simplicity of wiring or accessibility of connections. In case of trouble, or where one must connect or set up the machine without expert aid, it is well to learn to trace the circuits and to test out for breaks, etc.

While to one unaccustomed to do this, it seems very difficult, a few suggestions may help. There are only two main current paths from one supply line through the apparatus to the other line—the motor circuit and the transformer circuit. In tracing either circuit, follow a complete metallic path from one supply line through the motor or transformer back to the other supply line. Where paths divide, they must come together again further on, and one must avoid simply chasing around some loop. The main circuit in outline on all resistance controlled machines is shown in Fig. 31.

Where no attempt to bring the motor contact into correct phase is made, a reversing switch is provided, Fig. 32, which changes polarity of transformer without disturbing the motor circuit. There may be a special switch to be operated by a small current through a magnet, Fig. 33. A timer connection may be added, as in Fig. 34. Several

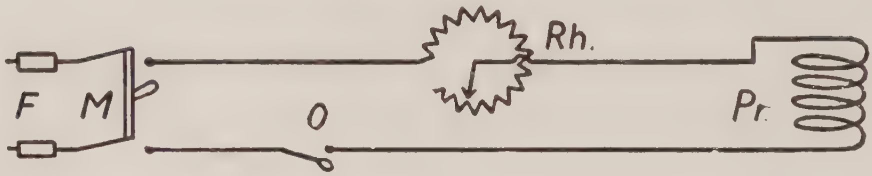


FIG. 31. Simple primary circuit, rheostat control.

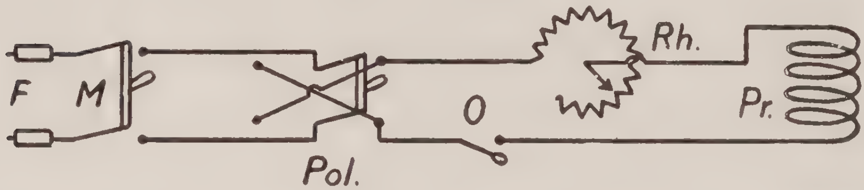


FIG. 32. Addition of reversing switch (polarity changer).

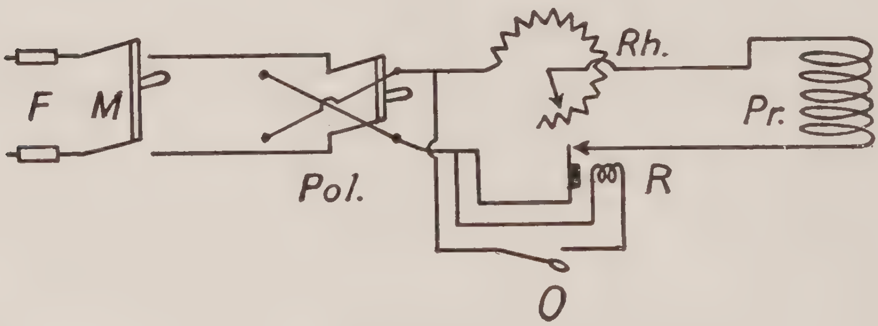


FIG. 33. Magnetic control-switch added.

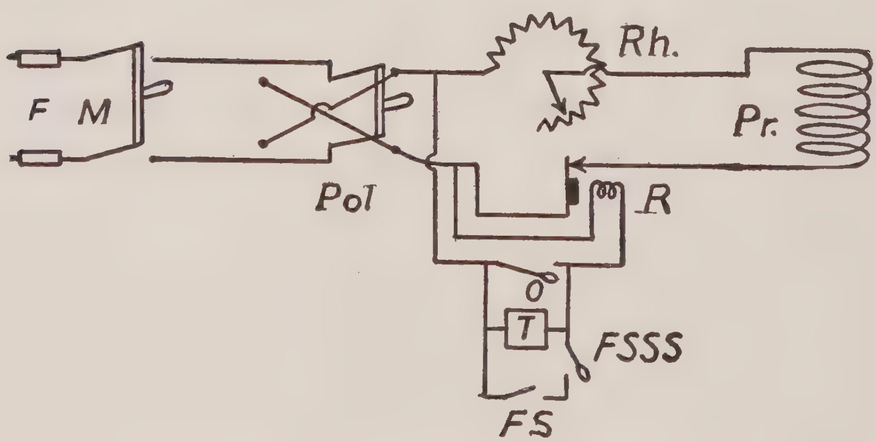


FIG. 34. Time switch and foot switch added.

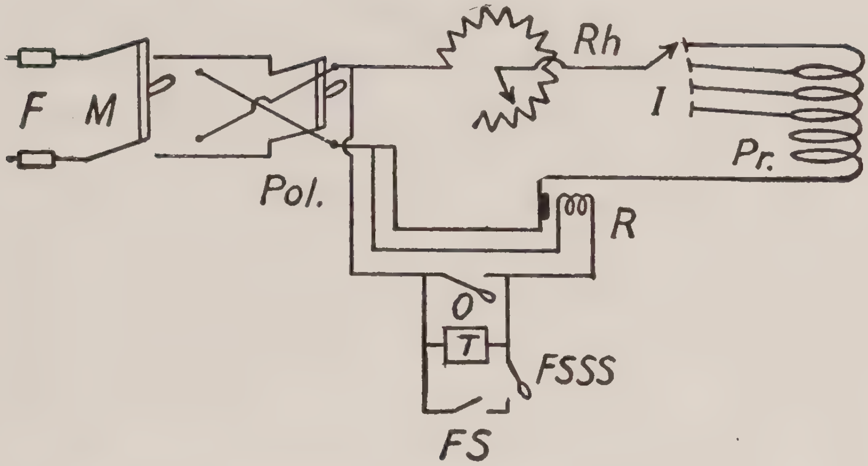


FIG. 35. Multiple taps ("Inductance taps") added.

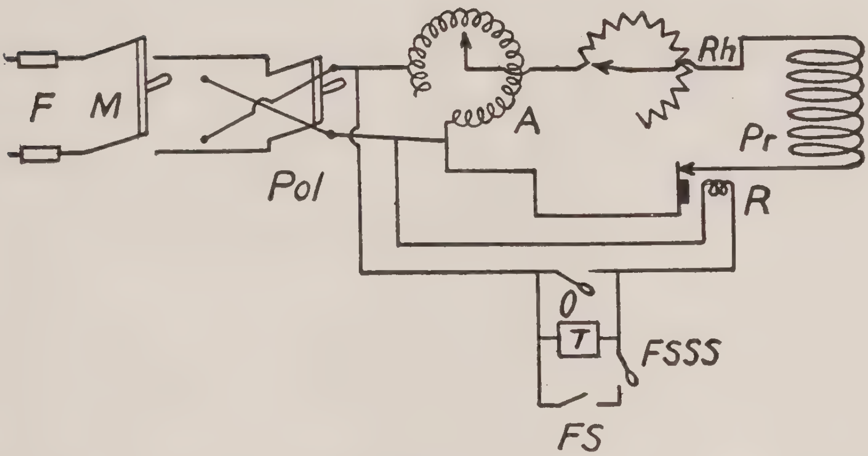


FIG. 36. Autotransformer instead of multiple primary taps.

A. Autotransformer.
C. Coolidge filament transformer
F. Fuses.
F.S. Foot Switch.
F.S.S.S. Foot switch safety switch.
G. Ground to case of transformer.
I. Inductance taps.
K.V. Kilovolt meter.
M. Main switch.
Mot. Motor.

O. Operating switch.
Pol. Polarity changer.
Pol.I. Polarity indicator.
Pr. Primary of transformer.
Prot. Protective resistance.
R. Remote control contactor.
Reg. Filament regulator.
Res. Resistance.
Rh. Rheostat.
T. Timer.

taps (inductances) may be brought out from the primary winding, Fig. 35. There may be a polarity indicator to show the way to place the reversing switch for a given tube connection. An autotransformer may be used as the control device, Fig. 36. The fundamental wiring scheme of all base hospital machines likely to be used is shown in Fig. 37. There are a considerable number of differences between the various machines but they all conform more or less to the same general scheme. Different models put out by the same manufacturer may be no more alike than the different makes. Whatever machine be used, to become familiar with the wiring will help to quickly overcome difficulties when they arise.

Locating Trouble.—Troubles in x-ray apparatus may be divided into two groups: (a) mechanical; (b) electrical.

Under mechanical, we may have worn bearings, worn or broken brushes, slip of rectifier on shaft; warping of wood, thus throwing shaft out of alignment. Care in oiling and keeping apparatus clean and dry will prevent most of these.

Under electrical troubles we have: (a) Improper connections; (b) break in conducting line; (c) loose connections; (d) failure of insulation.

To avoid (a) all wires removed from their connections should be labeled as well as the binding posts, etc., from which they were disconnected. Serious damage may be done if one attempts to operate with improper connections.

To find breaks, close switches and use test lamps, as directed in the following pages. When the lamp lights on connecting two points between which the resistance should be low, there must be a poor connection or a break.

Loose contacts are likely to cause irregular or intermittent action. Failure of insulation may cause current to

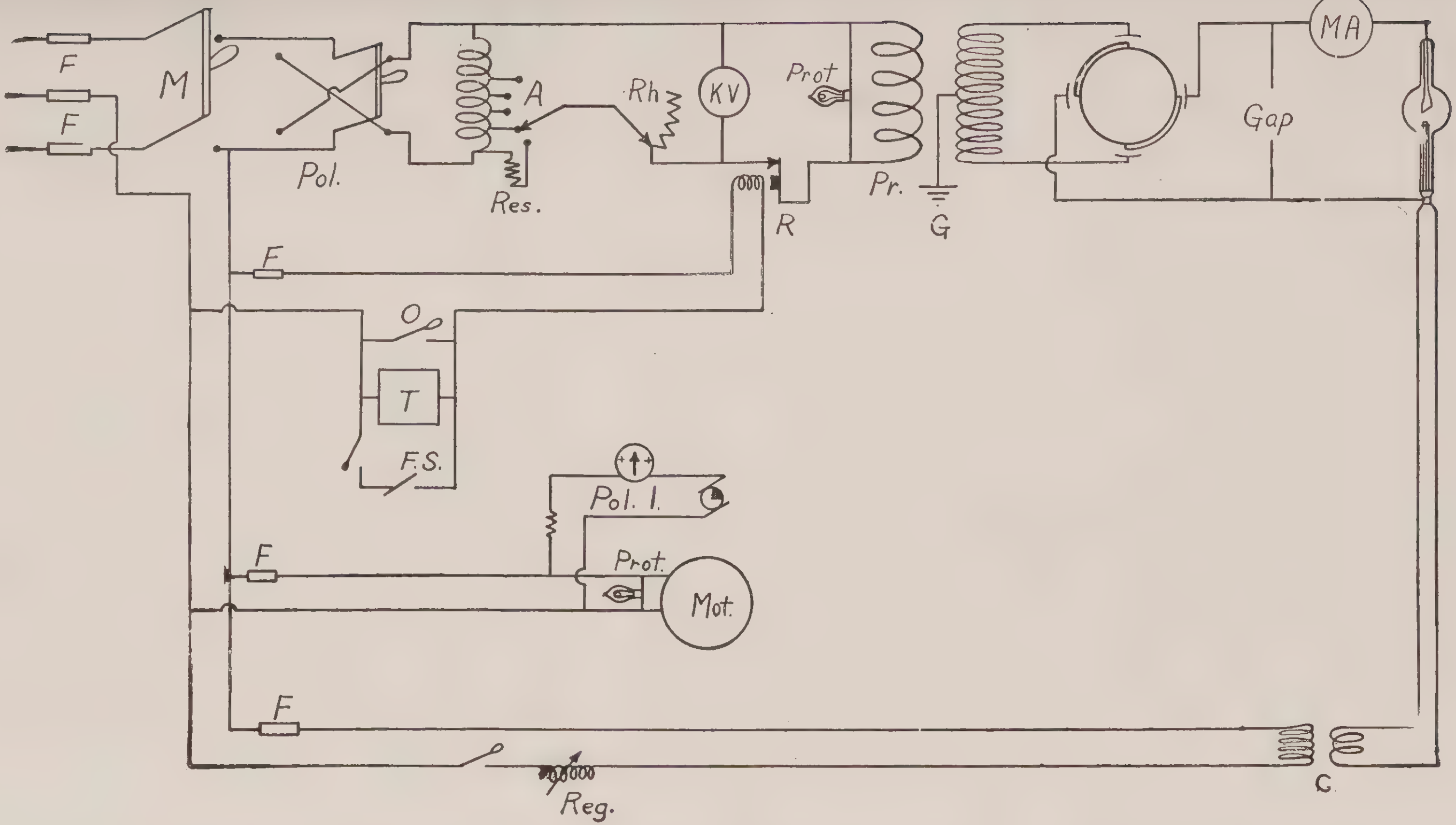


FIG. 37. Diagram of an x-ray machine, which, although it does not exactly represent any one machine, illustrates the fundamental connections of all of them. The principal low tension circuits are main primary, remote control, motor, and filament primary. **Key to lettering is on page 77.**

pass between two wires without going through the proper path.

If the fuse in any part of the circuit blows when only moderate power is used, open all switches and look for a short circuit; and if none is found insert a new fuse and test out on low power before attempting to continue work. Beware of the high tension line and terminals when hunting trouble on the primary or motor circuit.

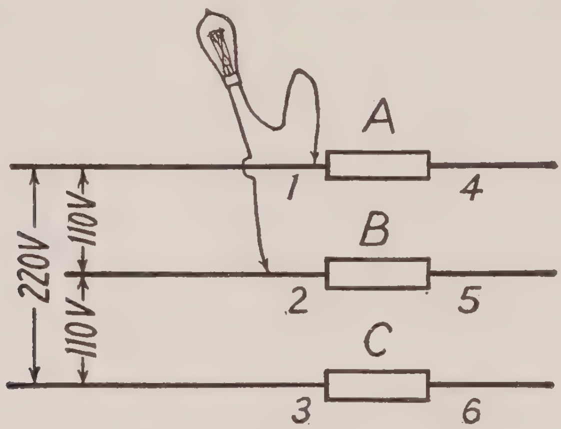


FIG. 38. Use of a lamp in trouble hunting.

Primary Circuit.—When a machine which has been operating fails to work, there must be trouble in either the supply or some part of the circuit insulation or wiring. The low tension side may be easiest tested by using an ordinary incandescent lamp of suitable voltage. Start back of the fuses on the main line, having motor and transformer switches *open.* Fig. 38.

Touch lamp terminal wires (bared ends) to bare wire at 1 and 2. If the line is "alive," a 220 volt lamp will light up to half brightness. Do the same for 2 and 3. Connect 1 to 5, and if lamp fails to light, fuse *B* is burned out. Or, if switches are closed and the lamp lights when connected to the opposite ends of a fuse, as 2 to 5, the

fuse must be burned out. Try 2 to 4 and 2 to 6; if all these connections give equal brightness to the filament, the trouble must be further along.

Close motor starting switch, and if motor does not start connect lamp across motor fuses one at a time. If a fuse is intact, it has so low a resistance that current will not pass through the lamp; if broken, the full line voltage appears at the break, and the lamp will light.

Finally, connect across the motor terminals, and if the lamp lights fully the trouble is *inside* the motor.

Follow the same general procedure in testing the transformer circuit, but *use great care to keep away from the high tension terminals;* also, be sure to set rheostat at lowest power.

If the lamp lights across the low tension terminals and no spark can be driven across a short gap between the secondary terminals, the trouble is inside the transformer and the chance of its repair by an operator is slight. If a break is near the terminals, it may sometimes be located and repaired; otherwise it must be sent to a manufacturer.

Secondary Circuit.—Outside of a break in the secondary coil or an arc to the case, the most common trouble in the secondary line is a complete or partial short circuit. This may occur in various ways:

1. In a cross arm machine, the insulation may break down between the cross conductor and the rectifier shaft.

2. In a disc machine, the disc may be dirty or carbonized, "shorting" around the periphery or to the motor shaft.

3. A high tension line may be in contact with the tube stand, a wall containing metal lath, the floor, etc.

The latter may, of course, be remedied at once by the operator.

In case of rectifier trouble, a Coolidge tube may be run directly on the transformer, *provided low spark gap and current is used so that the target does not get hot.* For fluoroscopic work there is no trouble in doing this, but for radiography time must be allowed between exposures for the target to cool.

Care of Tubes.—All tubes are fragile and may easily be damaged by fracture. A warm tube must not be placed on a cold support. Keep tubes free from dust and moisture. Do not allow either high tension wire to come within

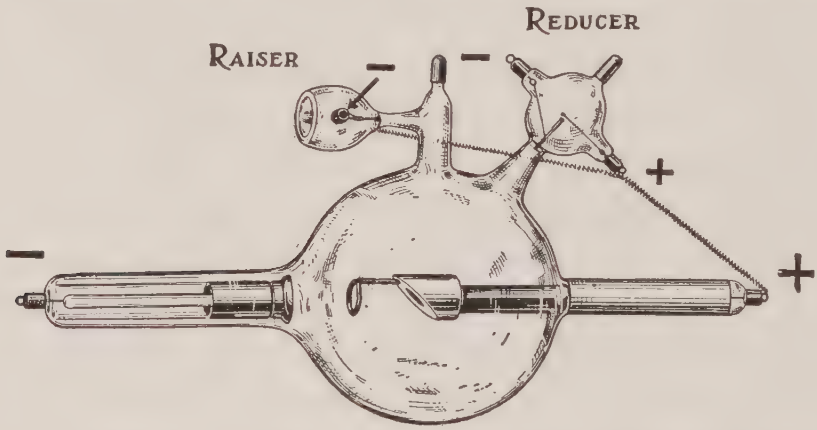


FIG. 39. Diagram showing softening and raising connections on Snook hydrogen tube.

five or six inches of the glass bulb. Always heat the filament of the Coolidge tube before attempting to pass current through it. Preserve cases or frames in which tubes are received for the return of punctured tubes or those requiring repumping. Use great care in softening gas tubes. Never soften a gas-containing tube with rheostat set for heavy radiography; use low power. If a tube is too soft, the rays emitted will not pass through the flesh. Better take more time and soften stepwise, testing after each *short* passage of current through the softener.

To soften the Snook hydrogen tube, pass through the reducer about 15 ma. five or ten seconds at a time. Re-

peat if necessary. Do not use more current; *use more time.* Always maintain polarity, as shown in Fig. 39. To harden the tube, pass through the raiser about 25 ma. (never more than 30 ma.) twenty seconds at a time. If the tube is excessively soft, disconnect spiral temporarily from + terminal of raiser. Connect anode wire to + terminal of raiser and cathode to — terminal of raiser. Run three minutes with 22 to 25 ma. Repeat if necessary. Replace spiral. Regulate tube before making exposure. It should test out at 2-inch gap and about 5 ma. The tube tends to harden a trifle during the first exposure when the tube is cold. To compensate, introduce a little more gas. Operate at 40 ma. for a medium focus tube. It will give much more service than at 45 to 50 ma. A sharp focus should be limited to 20 ma. and the time of exposure doubled. Use a broad focus tube for extremely fast exposures in making stomach and intestinal plates.

When a tube is in operation, the heat developed at the target is measured by the current x voltage. If this heat is produced at such a rate that it cannot be dissipated by conduction and radiation, the metal at the focal spot may be vaporized or melted and the tube ruined very quickly.

It is rarely necessary to do so-called flash or instantaneous work, and it can only be done at high tube cost. Properly used, a tube is capable of a large amount of work.

Do not use intermittent excitation during an exposure. In heavy work, if 60 ma. for four seconds overheats the tube at the gap needed, many operators close the switch for four separate seconds with three *intervals* of a second or more. The patient must remain at rest for seven seconds. The same exposure may be secured with 40 ma. continuously delivered for six seconds. In the latter case the danger of pitting or cracking the target is less and the

part need be held immobile for less time. This intermittent method has been suggested to overcome the tendency for voltage drop on heating gas tubes while in operation, but the allowable interval is too short to do much good.

Care of Motors.—1. All motors need oil at periods depending on the amount of use. Failure to oil may cause the bearings to wear enough to allow the armature to rub on the field supports and ruin the motor. Follow the maker's instructions, if any are given. Do not use too light an oil. An oil like 3 in 1 is good for sewing machines, but must not be used on power motors. Use real machine oil.

2. Most, if not all, motors used on x-ray machines have either slip rings or commutators, or both. Bearing on these are carbon or other conducting brushes. As the tension is low, these must have a good, even contact. Springs are provided to secure this, and if these break or get out of adjustment there will be either intermittent contact or none. The motor then either fails to start or it sparks at these bad contact points and corrodes the metal rings or commutator bars. If only slightly injured, they may be smoothed down by 00 sandpaper (not emery cloth), lubricated slightly with paraffin or *light* oil and rubbed off with a clean cloth. New brushes should be inserted *before* any serious trouble occurs. Be sure and put them in right, noting carefully how the old ones were placed.

3. Many motors have two sets of connections, one for *starting,* the other for *running.* Usually a double throw switch is used and marked for the purpose. Don't close on the running side and wait for something to happen. Don't throw over too quickly. Don't leave switch on starting position.

4. Keep motor clean and in as dry a place as circumstances permit.

5. If the motor fails to start, *open* the starting switch and test the fuse on the motor circuit; also be sure the line is "alive." If power is on and the fuse is intact, go carefully over the wiring to the motor, examine brushes, look at all external wires, and if no break is found it is fairly probable that some internal trouble has developed requiring technical motor knowledge for repair.

6. Be very sure not to connect a motor on a line for which it was not designed,—as an a.-c. motor on a d.-c. line; or a 220 volt motor on a 110 volt line, or the reverse; or an a.-c. motor designed for 60 cycles on a 40 cycle line, etc.

7. If an a.-c. motor fails to run at the right speed, do no try to operate tubes with it.

8. It is well to have the field and the armature of an x-ray motor protected from small sparks due to transient surges. Ordinary incandescent lamps in shunt serve very well for this purpose. Most machines have such protection, using either lamps, or special high resistances, or condensers.

Care of Transformers.—The attention of every roentgenologist should be called to the danger to the x-ray transformer arising from carelessness in operation. There are certain things which should never be done even though they might be done many times without damage.

1. Never operate at high applied voltage when the tube is taking no current, or on an open circuit, especially with rheostat control on high buttons. In this case the effective gap measuring the strain upon the insulation may be very much in excess of what is needed in practice.

2. High tension wires should not come in contact with or close to steam or gas pipes, electric service wires, metal ceilings or walls, metal tube stand, or the x-ray cabinet. Keep them away from things, where they belong. When

a discharge occurs from one high tension line to the earth the danger to the insulation of the transformer may be greater than in the case of a discharge between the two lines.

3. In all cases when starting up the machine test out for proper operation on low power and especially be careful not to attempt operation of any kind of tube with rectified current of wrong polarity. If, on moderate filament current and a low power setting, no current is drawn through a Coolidge tube, reverse the polarity and again test. After a machine is once up to synchronism it will very rarely change polarity while running, but it may do so in case of a momentary interruption of service or unsatisfactory line conditions. It is wise, whenever lights operating on the same power circuit as the x-ray apparatus become dim or are temporarily extinguished, to throw the machine to low power and again test for polarity.

4. Look to the oil level about every two months and record the date on a tag attached to the transformer. If the level is low, add more oil until all the coils are properly covered. Be sure to use *transformer oil* that has not been open and exposed to dirt and moisture. Wipe oil and dirt off the top of the transformer case.

5. Be sure that the transformer is adequately protected against surges by a suitable type of protective resistance.

Care of Batteries.—The only type of battery likely to be met in x-ray practice is the storage battery. This is sometimes used for portable coil work, and quite often to light the Coolidge filament. Each separate cell of a storage battery adds about two volts to the line. For any given voltage, then, half as many cells must be used as volts are needed. This voltage is independent of the size of the cells. A storage cell does not store electricity; it

uses electricity to cause a chemical change in its plates, and when it is discharged this chemical change is reversed and electric current flows from the cell. The amount of chemical change on proper charge is in proportion to the charging current and the time of flow, and is estimated in ampere-hours.

Thus, a 10 ampere-hour battery will deliver ten amperes for one hour, 1 ampere for ten hours, ½ an ampere for twenty hours, etc. Too rapid charge or discharge should be avoided because of damaging the battery.

The storage battery consists of two sets of plates, each containing a salt of lead held in some sort of small lead pockets, the whole being immersed in a solution of sulphuric acid. In a single cell, all the positive plates are joined together, likewise all the negative, and these sets must not be in contact. The negative of one cell must be joined to the positive of an adjacent one, leaving one + and one — for external connection. The ampere-hour capacity depends on the area of + and — plates per cell.

The following are the main points to be kept in mind when using storage batteries:

1. They must be charged on *direct* current.
2. The charging rate given by the maker should not be exceeded.
3. The discharge rate allowable should not be exceeded.
4. Loss of electrolyte by evaporation must be replaced by adding distilled water, rain water, or as pure water as can be had.
5. Loss of electrolyte by accidental spilling must be replaced by adding an *acid solution* of the proper density.
6. In making up an acid solution, never pour water into the acid, but pour acid slowly into the water.

7. Never let the solution get so low as to leave a portion of the plates bare.

8. Do not overcharge, nor discharge after the voltage falls below 1.8 volts per cell.

9. Do not let the battery freeze.

10. Do not let the battery stand idle for long periods. If it must be laid up, charge it fully and draw off the solution. For short periods, put a high resistance across its terminals and let it slowly discharge, and charge it up again at intervals.

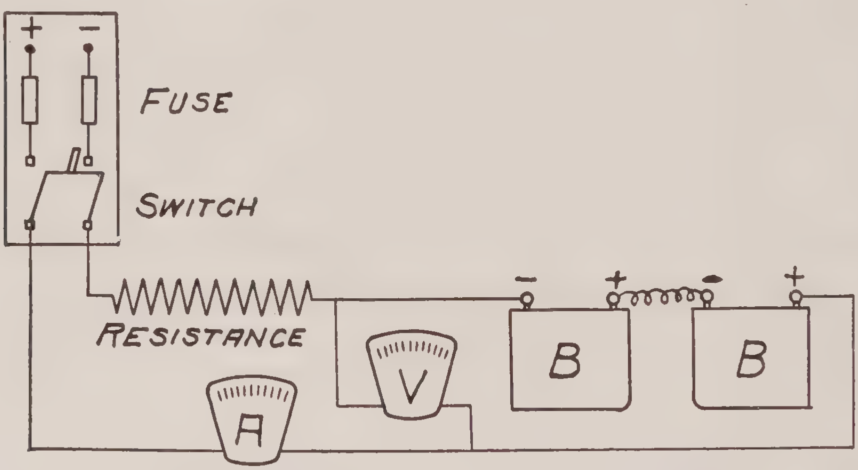


FIG. 40. Storage battery charging: *BB*—two cells in series; *V*—voltmeter; *A*—ammeter.

11. If overheated by too high current passing in or out, the active material is likely to crumble and fall to the bottom of the cell and cause a short circuit, whereby the battery discharges internally.

12. The discharge voltage falls quite rapidly after a battery is first charged, then more slowly until nearly discharged, then rapidly. When used on a Coolidge filament, which requires about four amperes, it is well to pass twelve or fifteen amperes through a suitable resistance for three or four minutes to bring the voltage down to the steady state the first time it is used after charging.

13. A small voltmeter is very useful in charging a battery, and a suitable resistance to bring the line voltage down to that required in charging should always be at hand. Either a voltmeter or a test for acid density may be used to indicate full charge.

14. Do not fail to disconnect the charging line before using on a Coolidge tube.

15. Storage cell terminals are almost sure to corrode; scrape clean when connecting.

The charging connections are shown in Fig. 40. If the battery has any charge, it will deflect the voltmeter in the same direction when discharging as when charging. Connect the voltmeter in the right way before starting to charge, and it will tell you whether you have connected to the charging line correctly. The ammeter may be omitted if one knows that the charging current is neither too large nor too small.

Emergency Provisions.—In military x-ray work it is of the utmost importance that apparatus be kept going at all times to meet the demands that are placed upon it. The roentgenologist must keep in mind the human lives dependent on him, and he must make every effort to repair, improvise, or do without whatever piece of apparatus may fail in the rush of work. There may be loss of time in securing replacement parts or repair assistance, and during this delay the plant must be maintained in operation. The following are some suggestions for emergencies.

Polarity Indicator.—This piece of apparatus may be classed as a luxury, and in case repair cannot readily be made no interruption of service is warranted. With a gas tube, polarity is readily shown by the appearance of the tube. Correct polarity results in a uniform color and inverse in a series of rings. With a Coolidge tube the milliammeter serves as a guide, for no current will flow

through the tube in the inverse direction. If the meter registers, the polarity is right. Always test on low power to avoid puncturing the tube. Spark gap may be used as an index if the meter also has failed, since on the same control setting the gap will be greater when the tube is not taking current than when it is.

In case of burnout of the resistance, sometimes included in the polarity indicator circuit, an incandescent lamp may often be substituted. Never attempt to connect up without the resistance.

Milliammeter.—In working without a milliammeter the appearance of a Coolidge tube gives no idea as to the amount of radiation produced. If the machine is on a steady power line the transformer chart may be used as an accurate means of obtaining a setting of the machine. Suppose a 5-inch gap and 40 ma. is desired, refer to the chart and find which control button must be used. Then, instead of using the chart in the customary way, set the gap for 5 inches and vary the filament temperature until the spark is barely able to break the gap. The milliamperage will now be right—40 ma.

The appearance of a gas tube is somewhat of a guide to tube current, but if an accurate chart has been made of the machine it is safer to refer to that. At what appears to to be a working setting, measure the spark gap. Then see what current corresponds to this gap on the control button used.

In working under uncertain conditions, *be sure that the spark gap is as high as it should be.* A difference in tube current will affect only the quantity of radiation; a difference in voltage not only changes the quantity but the penetration as well.

Timer.—If the timer fails, exposures may be made according to the second hand of a watch or by counting

seconds. "One thousand one, one thousand two, one thousand three," etc., is a convenient method, and a little practice will enable one to keep close pace with a stop watch.

Remote Control.—In case of failure of the remote control magnet coil or another device in its circuit the customary operating switch will be of no service. It is possible, in some instances, to wire around the remote control switch, or block it closed, and operate from an auxiliary switch in the main circuit, such as a pole-changing switch. Of course, care must be taken to *always close the switch the right way*, otherwise there is great danger of tube breakage and sparking to the patient on inverse polarity. Or, in some cases it would be more convenient to operate by holding the remote control switch closed with a stick during the exposure.

Protective Resistance.—If the shunt resistance or condensers protecting against surges become broken or unserviceable, do not leave the circuits unprotected, since a more vital element may be damaged. An incandescent lamp of proper size and voltage (usually 220 V, 16 candle power, carbon filament) connected in shunt as shown in Fig. 13 is very good protection.

Motor or Rectifier.—In case of breakage of the rectifier or burnout of the synchronous motor, work may still be done by working on *low power* and letting the Coolidge tube do its own rectifying. (If the rotary converter fails on a direct current installation and alternating current is not available, nothing can ordinarily be done.) Set the rectifier in position so there will be a minimum of sparking distance to the collector brushes, or wire across these gaps. Leave the motor switch open, or in case it must be closed to get current through the main primary and filament primary circuits, disconnect the lead wires to the motor and tape the ends to prevent short circuit. Then,

starting on low power, set the tube for a 5-inch working gap and 5 ma. All Coolidge tubes will operate self-rectifying so long as the target does not become hot enough to emit an appreciable number of electrons. Do not work at more than 5 ma. and *do not let the target heat to redness,* or the tube will no longer rectify, and will very soon be ruined.

Spark gap is not a reliable guide to working voltage in a self-rectifying tube, since the inverse voltage is higher than the working voltage. (See page 37.) The excess over working voltage depends on the resistances in circuit and the type of control. To secure a setting of 5-inch working gap and 5 ma., refer to the chart of the machine and set to 5 ma. on the proper control button. Check by seeing that the spark gap is approximately that at which the chart line crosses the vertical axis of the chart. Be sure that the working voltage is what it should be to give rays of adequate penetration. Do all radiographic work either by giving increased time or by using intensifying screens and exposing as with the bedside unit.

Autotransformer or Rheostat.—On many machines having combined control, a failure of one of these elements would merely necessitate leaving it out of circuit and controlling by the other. Broken wires or burned-out coils in a rheostat are easily wired across, but a failure in an autotransformer is a much more difficult proposition. In case it is necessary to improvise a complete new control, this may be done by building a water rheostat.

Fill a large wooden pail with water and drop into it a lead or iron plate of about 60 square inches area with wire attached, for an electrode, as in Fig. 41. Suspend securely, and so its immersion may be definitely controlled, a smaller

piece of metal as the other electrode. Immerse it slightly to correspond to the lowest power setting desired. Test it out, and add ordinary salt slowly, making sure that it is all dissolved, and testing at intervals until the desired low-power setting is reached. Pure water is a very poor conductor of electricity, and the addition of salt lowers the resistance of the solution to the desired amount. Higher powers will be secured by immersing the upper electrode deeper in the solution and lower powers by withdrawing it.

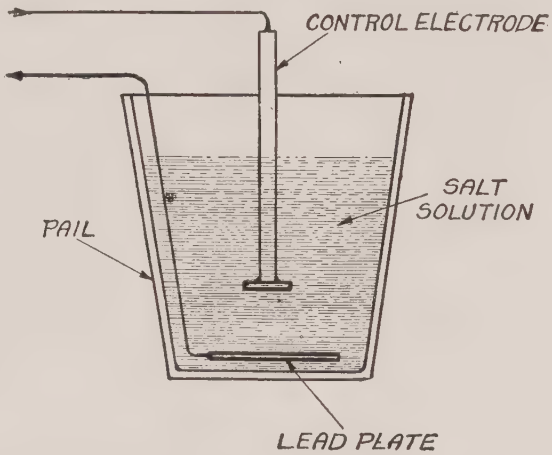


Fig. 41. Emergency rheostat for control of primary of x-ray transformer.

It may be noted that in case of failure of both rheostat and auto-transformer on 220 volt machines, as a general rule we may secure reasonable operation by applying 110 volt service directly to the 220 volt connections on the transformer. Then select, when using the Coolidge tube, that current which will give a 5-inch gap and modify exposures if the current is greater or less than that usually employed.

Fuses.—In case the supply of plug or cartridge fuses runs out *never wire across the cut-out block with copper wire.* Have an ample supply of 10 ampere fuse wire on hand and include the proper amount of this in the circuit. To fuse for 30 amperes use 3 strands in parallel, for 50 amperes use 5 strands, and so on, Fig. 42. For less than ten amperes the wire may be whittled down to smaller cross section. The length of the fuse wire does not alter

the current at which it will blow, nor does the voltage of the line on which it is used.

The above suggestions cover most of the cases that are likely to occur. The resourcefulness of the roentgenologist is relied upon to cover the others and to keep his plant in operation so long as he has electric power, a transformer, and a tube. With these three essentials and a little ingenuity he should be expected to generate x-rays and do creditable work in an emergency rather than shut down and wait for assistance.

Ordering Supplies and Repairs.—Much delay and incon-

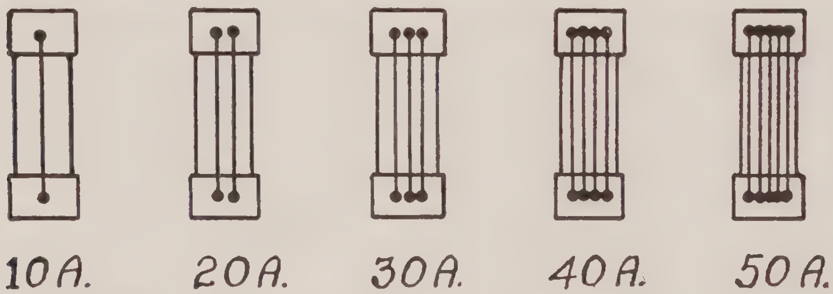


FIG. 42. Method of using 10 ampere fuse wire to secure capacity desired. It may be soldered to the brass ends of the burned out fuses.

venience will be avoided if care is taken to state explicitly just what is wanted and the exact quantity. The work of the supply depot must be done by people who cannot be familiar with every minute detail of x-ray equipment, and mind readers are scarce.

When ordering a machine specify:

1. Type of current, a.c. or d.c.
2. The frequency of cycles, if a.c.
3. The voltage.
4. The power available in kw.
5. Gauge and length of wire needed to connect up.
6. If d.c., always specify a rotary converter and the d.-c. voltage.
7. Be sure to state that the motor, transformer and

Coolidge filament transformer when used on 154 volts or 70 volts a.c. from a rotary must operate properly.

Thus—220–volt–a.c.–60 cycle–10 kw—specifies a definite type of machine.

In ordering repair parts state the name of the apparatus, the maker, if known, and either give a drawing or such an exact description or name as to identify the piece required. Sometimes one may return a broken or defective part as a complete identification.

In case of supplies be sure to give the amount and any other information that will make your needs clearly understood. Thus an order for "an x-ray screen" is meaningless; one for a "10 x 10 inch Patterson fluoroscopic x-ray screen, mounted with lead glass," is definite.

Never fail to give complete address to which goods are to be forwarded.

No small part of what we protest against as "red tape" is made necessary by failure of individuals to convey a *clear* idea of what they desire.

When possible confine your requests to those articles specified in the supply tables.

Induction Coils.—It sometimes becomes necessary to work for a time, at least, with an induction coil. While not often used in this country one must be prepared to use it if need be abroad.

Coil Characteristics.—A good induction coil should be able to give a heavy discharge at a voltage high enough to break a 10- or 12-inch gap.

Under no circumstances must a coil be operated at high power long enough to heat the insulation, as the insulating power is much reduced at high temperatures. Each coil has its own characteristics which determine its best working conditions. These characteristics depend on the primary and secondary resistances, on the amount and

quality of iron in the core, on the number of turns in the coil, and on the mode of winding.

The most undesirable feature in coil operation for x-ray work is the unavoidable inverse which must be minimized in the use of the ordinary tube. The amount of inverse depends on the coil, the interrupter and the tube. A coil having a considerable number of primary turns and but little "magnetic leakage" gives less trouble with inverse than other types.

The direction of secondary current while the primary is increasing is opposite to that during a *decrease* of primary current. Generally it is possible to reduce primary current at a greater rate than that at which it can be built up. Hence the "break" voltage is usually higher than that at "make." The current of higher voltage is useful in the tube, but the inverse is not only ineffective for ray production but is a source of positive injury to the ordinary tube. If the make current could be caused to rise slowly enough, the resulting secondary voltage would not force current through the tube. In practice this is not possible, although the voltage giving "inverse" may be very much smaller than that giving "direct."

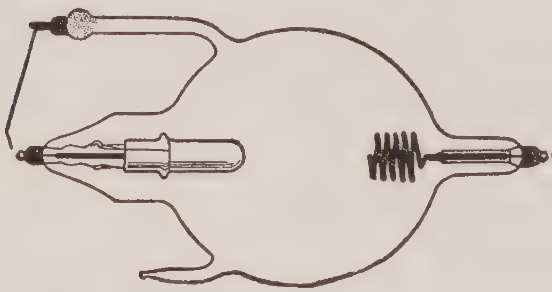


FIG. 43. Valve tube.

Valve Tubes.—In order to reduce "inverse" as far as possible, various unsymmetrical tubes, Fig. 43, have been devised; these offer much greater resistance to discharge in one direction than the other. Such valve tubes are often supplemented by a series of small spark gaps which are readily broken down by the "direct," but not by the lower voltage "inverse." These devices all reduce the energy

available for x-ray production. Fig. 44 shows a tube designed to indicate the presence of inverse. If there is no inverse, only one of the metal terminals at the gap

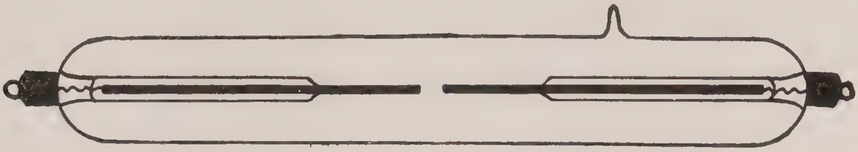


FIG. 44. Vacuum tube oscilloscope.

will glow. If both glow to the same extent, inverse current is present.

Fig. 45 shows the wiring diagram for a coil with mer-

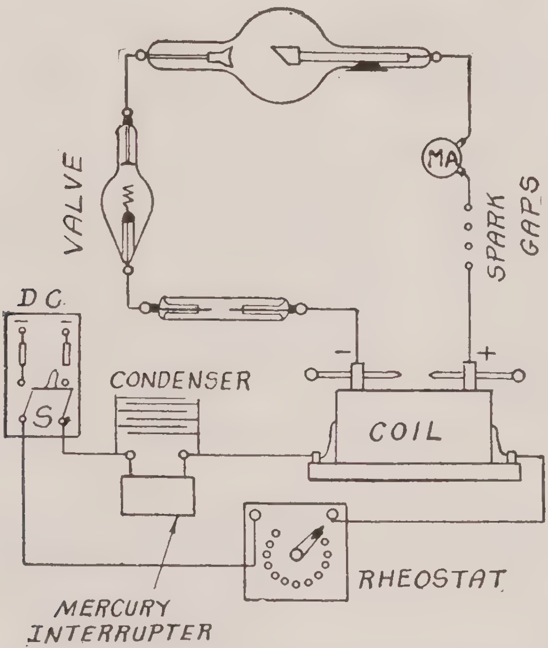


FIG. 45. Complete connection for the operation of tube with induction coil and mercury interrupter.

cury interrupter, condenser, oscilloscope, valve tube, and series spark gap. Note that the milliammeter is next to the tube.

When the spark gap is placed between the meter and the tube, leakage across the gap may make the reading

much above the current actually passed through the tube.

Interrupters.—The secondary voltage of an induction coil is the result of *change* of current in the primary. It is evident that we cannot have the primary current grow indefinitely, so we must allow it to decrease and increase alternately. The value of the secondary voltage for a given coil depends entirely on the *rate* at which the *primary current* is changed. Thus, if a current of 80 amperes should be reduced to 0 amperes in .02 seconds, the current

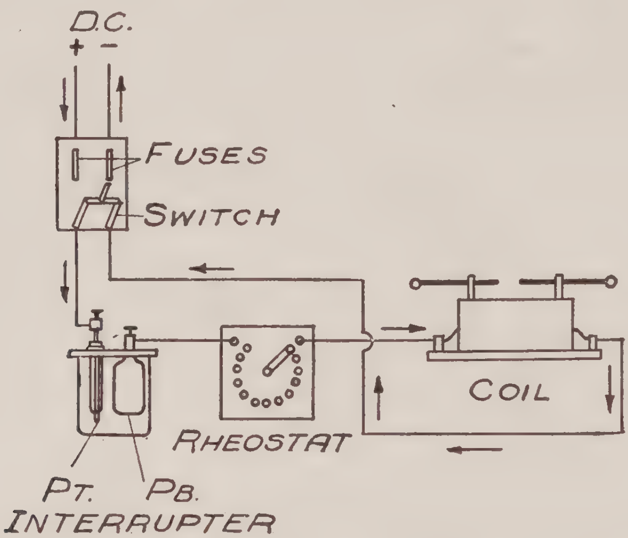


FIG. 46. Wiring for induction coil with electrolytic interrupter.

has changed at a mean rate of 4000 amperes per second. If it required .04 seconds for the same change, the rate is 2000 amperes per second. The mean secondary voltage is twice as great in the former case as in the latter.

As induction coils are intended to operate on an interrupted direct current, some device must be used to open and close the circuit. The early interrupters were of the vibrating hammer type, but these have largely been superseded by others much better adapted to x-ray work. They are still used on small outfits where large power is not drawn.

The Wehnelt Interrupter.—The Wehnelt interrupter consists of a lead and a platinum electrode immersed in a solution of sulphuric acid. The amount of platinum exposed to the solution is usually variable at will. When connected as shown in Fig. 46, the application of sufficient voltage will result in the formation of a non-conducting layer between the solution and the platinum, thus interrupting current flow. The layer is very quickly dissipated, reëstablishing current only to be again formed, etc. When

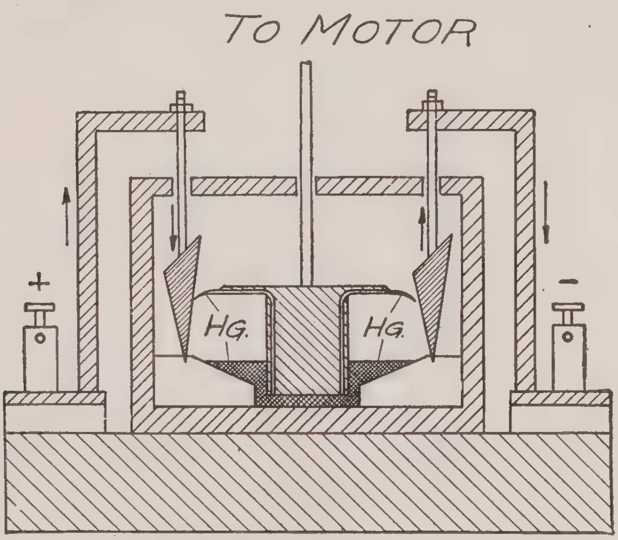


FIG. 47. Centrifugal jet mercury interrupter.

only a small amount of platinum surface is exposed, the number of interruptions per second is high and the current is small. Greater immersion lowers the number of interruptions and draws more current.

Operating Notes.—1. The solution should contain 30 to 35 per cent pure sulphuric acid. In mixing, be sure to add *small* amounts of *acid to water,* allowing the mixture to cool after each amount is added. *Never pour water into the acid.*

2. *Do not use a condenser,* as is done with the mechanical interrupter.

3. If your point or points are adjustable, use little or no resistance in series with coil and interrupter on a 110 volt circuit.

4. Your coil may not have the correct self-induction for use with a Wehnelt, at least over a wide range of frequencies of interruption. If *inverse* is prominent, try a greater amount of platinum exposed, thereby lowering the frequency of interruption.

5. Do not run too hot, and if possible enclose interrupter in a sound-proof box, or place outside.

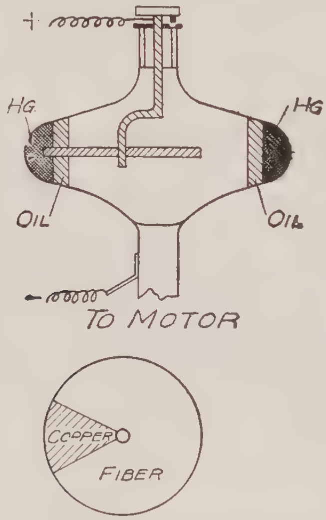


FIG. 48. "Rotax" interrupter.

6. Be sure that connections are made to the proper terminals.

7. Do not try to operate on alternating current without a rectifier. This has been done in a few instances, but is not advised.

The Mercury Interrupter.—Various forms of interrupters using mercury have been invented, and have some advantages for use with heavy coils. They allow variation in two essential particulars, viz., number of interruptions per second and relative duration of make and break. Two forms are in common use. In the jet type,

Fig. 47, a centrifugal pump throws small streams of mercury against V-shaped iron terminals. The motor speed determines the number of interruptions, and raising or lowering the iron decreases or increases time of flow relative to that of no current.

In the Rotax interrupter, Fig. 48, the mercury is thrown into a ring revolving with the case. An insulating disc with a small conducting sector is mounted so that it may be moved to and from the circumference. When in contact with the mercury, the disc rotates at a speed depending on the mercury speed and the amount of immersion of the disc. The latter is insulated from the case and is connected to an external binding post. The relative time of current "on" and "off" varies with the immersion of the disc in the mercury. A small amount of paraffin oil is used, forming a ring inside the mercury to prevent oxidation. A better plan, when the apparatus will permit, is to use illuminating gas in the case, which reduces contamination of the mercury and enables long periods of operation without refilling. If gas is used, a small burner should be connected to the cavity and kept burning, and the current should never be turned on until this light continues to burn, as severe explosions may result by spark ignition of an air-gas mixture. Recent forms have a safety valve to protect against explosion.

A suitable capacity must always be connected to the terminals of interrupters of this type. The amount of this capacity will vary with different inductances of the primary and to some extent with the frequency of the interruption.

Operating Notes.—Carefully read and preserve any directions furnished by the maker of the interrupter used. If none are at hand, and trouble arises, some one or more of the following may be found to account for it.

1. *No current in any position of the disc.* Look for poor contacts, either from bad brush on revolving case, loose binding posts, or broken wires. The mercury should be examined to be sure that there is enough and that the oxide does not prevent contact.

2. *Very heavy primary current and little or no secondary current or voltage.* Examine capacity to see if it is punctured; if so, renew at once. If condenser is all right, see if disc is free to turn and is not immersed too far by reason of an overcharge of mercury.

3. Be sure to keep the required amount of oil in the case, as, if there is too little it becomes carbonized by the arc and gives trouble.

4. The mercury must be kept clean. When it is dirty, oxidized, or emulsified with oil, either clean by filtering and washing or put in new mercury.

A coil in which a current is changing always develops an active opposition to the alternation of current. On an attempt to increase the current, the coil acts as an opposing generator, and when current falls the generator action reverses. This action is due to *self-induction.* The opposing voltage, when we change current at the rate of 1 ampere per second, is an important factor in behavior of the coil, and is named the *coefficient of self-induction.*

On account of self-induction, no really instantaneous change of current can take place, and the response to variable voltage will depend on this feature of the coil and on the rate at which we attempt to make current changes. Each coil is an individual in this respect, and one should find by trial the conditions under which it operates best for each purpose, and then adhere to these conditions. A little time spent in this way will save much time and annoyance later.

Tubes for Use with Coils.—The current wave from a

coil is quite different from that from a transformer. The current consists of a series of short rushes with considerable

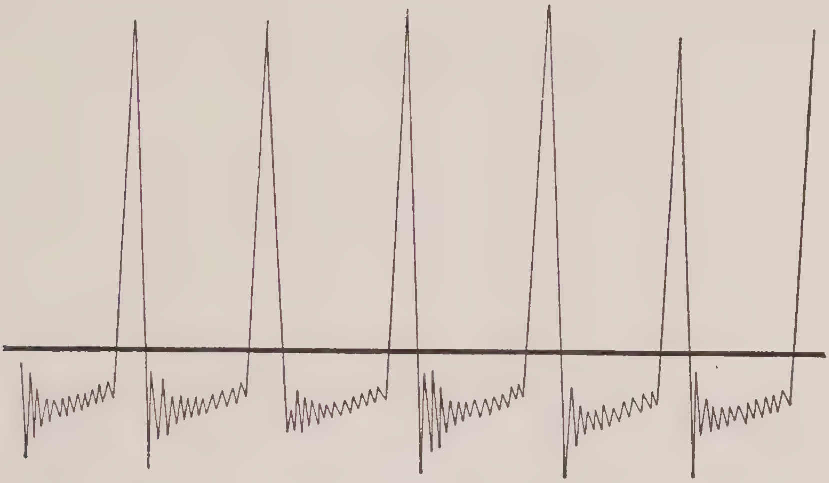


FIG. 49. Oscillogram—induction coil current with a gas mercury interrupter.

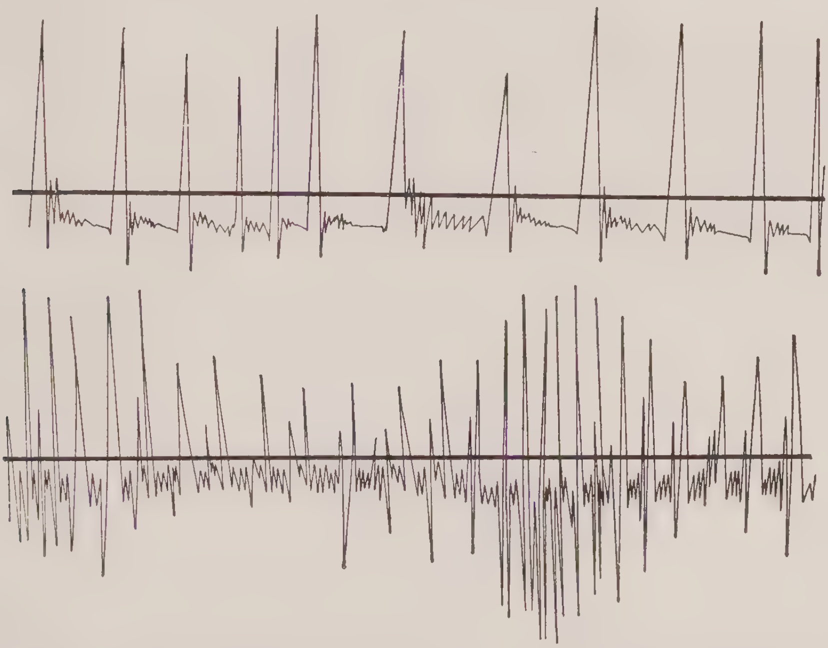


FIG. 50. Oscillograms—induction coil currents with Wehnelt interrupter.

time between each impulse. Fig. 49 shows the variations of current with time on an induction coil with a good mercury interrupter. Fig. 50, two curves with a Weh-

nelt break. Note the large amount of inverse in the latter. In order that the tube current may not lower the voltage below the required point, it is essential to have gas tubes at relatively high vacuum, or hard. Thus we must have *small* tube currents.

Readings.—Milliampere and spark gap readings are far less reliable guides for radiography when using coils than on transformers. The gap shows peak voltage which may be high but transient. As the ordinary milliammeter indicates the *difference* between direct and inverse, one may get 0 reading and yet have the tube operating.

Portable Coils.—Portable coil outfits are so varied as to make brief description impossible. Those heretofore in use were largely of the "Tesla" type.

The electric lighting current is stepped up to about 2000 volts by a small step-up transformer, if the supply is from an alternating current line.

If the current is direct, the circuit is made and broken by some form of vibrating interrupter, giving much the same effect in the transformer as though an alternating current was used.

The 2000 volt current from the secondary of the step-up transformer charges a condenser. The condenser is discharged through a few turns of wire wound around the outside of a secondary, consisting of a large number of turns of fine wire. The discharge of the condenser is at an enormous frequency, and high voltages of high frequency are generated by the Tesla coil.

As the current delivered by the Tesla coil is alternating, a different form of tube must be used from that for other types of x-ray generator, if best results are desired. This special tube has a valve arrangement built into it which tends to suppress one wave of the current.

Fast Work.—From what has gone before, it is clear that

the same radiographic density can be secured in a great variety of exposure times. Certainly, for the inexperienced operator high speed is inadvisable. If 3 to 10 seconds would give the most desirable exposure, an error of one second would give a fairly good plate. On power such that ½ second is best, an error of one second in judgment or execution would exceed the latitude of the plate.

The conditions for fast work are:

1. Small target-plate distance.
2. Very large current.
3. High voltage.
4. Fast plates or intensifying screens.

The disadvantage of the first is distortion and haze of outline, due to size of electron focus; of the second danger of melting the target, and difficulty in setting to proper voltage. When high voltage is used, the evening up of penetration, as well as the increase of scattering with high penetration rays, tends to give flat plates. Very fast plates and ordinary plates with screens allow little latitude of exposure. Screens also may register their own dust or surface defects.

Photographic Density and Character of Negative.—Considerable objection has been made to the use of photographic plates, films, or paper in the study of this type of radiation. Much of the adverse criticism is well founded, for the following reasons: The unaided eye is a poor judge of comparative absorption of light by a negative; only by means of comparison involving photometric apparatus can one be fairly sure of correct measurement. If an unexposed or clear portion of a negative transmits an arbitrary amount of light, Q, an area transmitting 50 per cent or half as much would be said to have an opacity of 2; and the logarithm of this opacity would be named the

density of this portion of the negative. It has been found that density determined in this way is proportional to the amount of silver reduced per unit plate area. Transmissions, opacities, and densities are related as follows:

Transmission per cent		Opacity O	Density D
100	(Clear glass)	1	0 (Log 1 = 0)
90		10/9 = 1.11	.104
80		10/8 = 1.25	.223
70		10/7 = 1.43	.358
60		10/6 = 1.66	.507
50		10/5 = 2.00	.693
40		10/4 = 2.50	.916
30		10/3 = 3.33	1.203
20		10/2 = 5.00	1.609

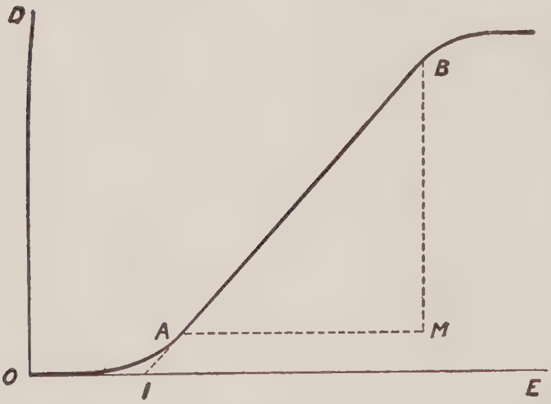


FIG. 51. The relation between exposure and density of a photographic plate. Below *A*—underexposure. Beyond *B*—overexposure. *OI*—inertia of the plate.

When the intensity and quality of radiation remain fixed, the exposure varies only with the time. Suppose that $Kt = E$ where K depends on the nature and intensity of the radiation. Plotting E and D, there remains a line approximately as shown in Fig. 51. A portion of this line AB is nearly straight; below A and above B it is curved somewhat, as shown. If AB is produced to cut the density axis at I, OI is named the *inertia* of the plate. The portion AB of the plot is the region of proper exposure. Above B the den-

sity fails to increase in proportion to exposure and is the region of over-exposure. In fact, if the exposure is carried too far, the density falls off and a reversal may occur.

The slope of the line AB or the ratio $BM/AM = \gamma$ is named the development factor: For under-development γ is small and contrast is low. For longer development, the line swings counter-clockwise on I as a pivot. The point where one should stop is a matter to be governed by experience. In ordinary photography γ ranges from .8 to 1.3; probably no accurate determination can be made of the most desirable conditions until some agreement is reached as to the best quality of negative for specific purposes.

The *inertia* of the plate is not affected by time of development. A fast plate is one where OI is small. A plate of great latitude is one where exposure difference for A and B is large. The speed of a plate is determined by the inertia OI and is expressed in arbitrary sensitometer units.

The conditions during development fix, for a given plate, a time beyond which development should not be carried on account of fog. In x-ray work, the use of high penetration on thick patients tends to fog by cross scattered radiation, and this may be noticed long before developer fog becomes troublesome.

As a means of measurement, we may utilize different portions of the same plate under different physical conditions to learn whether the radiation effects on the various portions are or are not alike. For example, if a *constant* voltage is used at constant distance, the exposure varies as the product of current and time—so that 20 ma. for 2 seconds and 40 ma. for 1 second should give equal density with equal development, provided the rise and fall of voltage be alike in the two cases.

Certain terms are in common use when negatives are described, and should be understood.

Contrast refers to the amount of difference in darkening for a small difference of exposure. Thus, if rays pass through bone and flesh, there is a variation in the amount of radiation *reaching the plate*, due to difference of absorption; when this results in a marked difference in darkening, the negative is "contrasty." Contrast depends on the nature of the plate and the development, and to a great extent on the quality of the radiation used. If the beam is too penetrating, contrast is reduced, for if rays pass through bone and flesh equally well, there would be no contrast. Too "soft" radiation will fail to get through the denser portion and will give high contrast but poor detail in thick parts. The amount of contrast to be desired will vary with the work to be done. A plate showing fine bone detail and contrast may show but little of the soft tissue.

Detail refers to the fineness of the marking of light and shade. Thus, a mastoid plate should show minute structure, or lines of light and shade should show sharp gradation or density change. Detail depends on:

1. Breadth of tube focal spot.
2. Distance of target from plate.
3. Distance of part to be radiographed from plate.
4. Complete immobilization of patient.
5. Correct exposure and development.

Exposure Table.—Many attempts have been made to work out exposure tables such that inexperienced operators can get favorable results. Without doubt the best work is done when spark gap, current, and time are chosen with reference to the individual case in hand, and any operator who cannot improve on the results secured by adhering to any single table is unfit for the work.

As a general guide in *starting* work, a uniform rather high gap may be used—say 5 inches, and a uniform target-plate distance—say 20 inches, except for chest, where 28 inches is advised. With all this understood, the average of reports from many sources gives the following table for a patient of about 150 pounds weight and a Seed x-ray plate. Some people prefer a *shorter* gap for most work [p-a head work excepted], and certainly with the ordinary solid tungsten target, medium focus Coolidge tube, better negatives result from proper exposure on a four-inch gap than on a five-inch one; this will require about 50 per cent increase in time of exposure for the same distance and current.

Part	Time: sec.
Head, A-P	12
Head, Lat.	6
Neck	3
Shoulder	3½
Elbow	1½
Wrist	1
Kidney	3—5
Bladder	3—5
Hip joint	5—7
Pelvis	5—7
Knee	2
Ankle	1½
Lumbar spine	5—6
Teeth (slow film)	4
Teeth (fast film)	1½
Chest (at 28″)	2½—4

All exposures on 5″ gap, 40 ma. 20″ distance except chest, which is at 28″.

NOTES: (a) For parts above average thickness, increase time considerably more than in proportion to increase of thickness.

(b) If it is *necessary* to work at other distances than 20″, use the following table of multiplying factors:

Distance	Time factor	Distance	Time factor
15″	.6	21″	1.1
16	.6	22	1.2
17	.7	23	1.3
18	.8	24	1.4
19	.9	25	1.6
20	1.0		.

For "Diagnostic plates," reduce time by ¼. For *double coated* Eastman films use half the time.

With intensifying screens no fixed rule can be given. A reduction factor may be found for the screen used as indicated on pages 112-114.

Plates and Films.—Photographic plates and films consist of a thin layer of gelatin containing a salt of silver and spread on glass or celluloid. Light and x-rays cause a change in the silver salt such that suitable chemicals, called developers, act on the portions that have received the radiation, changing the silver compound to metallic silver, and thus rendering those portions more or less opaque to light. The opacity produced will depend on the amount of radiant action, on the sensitiveness of the emulsion, and on the development. Those portions receiving much light or x-rays, when fully developed, may be quite opaque; other portions may be entirely or nearly transparent.

After development the plate is washed and placed in a "fixing" bath which removes the unused silver salt, as shown by the disappearance of the cream color of the emulsion, rendering the parts not radiated and developed transparent.

All plates sensitive to x-rays are also sensitive to ordinary light and hence they must be entirely protected from ordinary white light until finished.

The emulsion is an example of unstable chemical structure and may be injured by (1) moisture, (2) high temperature, (3) contact with other material, (4) exposure to light or x-rays, (5) bending. Plates should be kept in the original boxes, on edge, in a cool dry room, well protected from x-rays. No more plates should be put up in envelopes than are likely to be used in the next two or three days.

Filling Envelopes and Cassettes.—X-ray plates are used either in envelopes or in plate-holders, called cassettes. It is quite essential that in regular work the emulsion side should be toward the patient. To insure this when using envelopes, arrange the envelopes to be filled before darkening the room. Put black and yellow envelopes in alternation with the end flaps down, insert plate with emulsion side down, i. e., so that the flap will fold over the *back* of the plate; then insert the flap end first in the yellow envelope with the emulsion down, so that the flap of the outer envelope also folds over the back. Then place the smooth side of the envelope toward the target. A soft brush is useful to remove dust from plates and cassettes.

In using cassettes *without screens, put the emulsion side down.* This side can be determined by sighting across the surface, as it appears dull as compared with the glass side, or touching the tongue to the extreme corner of the plate—the emulsion side will be slightly sticky. Form the habit of closing partly empty plate boxes *at once* after filling envelopes or cassettes.

Attention is called here to the new double-coated film which is used to considerable extent. In this case there is no difference in the two sides of the film and no at-

tention need be paid in placing it in the special holders provided. It should be borne in mind, however, that these films must be handled with great care. Finger prints are much more likely to show and both sides of the emulsion must be protected from moisture and scratches. Great care must also be taken not to wrinkle, bend or twist these films before exposure. For this reason it is undesirable to attempt to use them in the ordinary black or yellow envelopes usually supplied. They should be used in cassettes or in the special holder furnished for the purpose.

Intensifying Screens.—When using intensifying screens the usual practice in this country is to allow the rays to pass *through the glass* to the emulsion and then to the screen surface. Consequently the negative, when viewed with the emulsion side toward the eye, is *reversed* as to *right* and *left* as compared with the usual plate. The screen should be firmly fixed to the back of the cassette and should be kept *scrupulously* clean; wipe off dust with a *clean* cloth, and never touch the surface with wet or greasy fingers. *Insert cleaned plate with emulsion side up,* and be sure that the springs press the screen firmly against the plate. On account of the variable x-ray opacity of the glass at present in use, screen work with plates is rather uncertain. Be sure to keep screen clean by not letting it get wet, dirty, or dusty.

It is quite impossible to be sure of the speed of the various screens in actual use, inasmuch as this depends on so many conditions, such as amount of use, and the general care which has been exercised in handling, as well as their initial speed.

In order that the proper exposure may be given it is well to determine the multiplying factor by which the screen increases the normal speed of the plate. This may be easily done by the use of a film of proper size in the screen

holder, exposed at the same time with one in an ordinary envelope or container laid on top of the screen. This envelope should be cross-ruled with lines approximately ½ inch apart, and a heavy sheet of lead placed to cover all except one end division, being sure that film occupies this division. Make a very brief exposure at low power and considerable distance, using a timer, if one is available, and leaving the tube, machine, timer and distance unchanged; slide the sheet of lead back, leaving two divisions exposed; and repeat the exposure. Do this for all of the film and develop both films at the same time and in the same developer.

It will be evident that if there were 15 divisions, the one which was exposed first received 15 exposures, the next 14, etc. The last may be numbered 1, the next 2, etc. If it should be found that the film in the envelope, and not affected by the intensifying screen, required 12 of these exposures to give the same blackening as number one, with the intensifying screen, it is clear that 1/12 of the time required with no screen should be used. This procedure is somewhat more reliable if exposures can be through a rectangular block of paraffin, as the speed of some screens seems to vary considerably according to the filtration which the rays have received before reaching the emulsion. Fig. 52 shows such a pair of films for a particular screen. After the determination of the speed, it should be marked on the cassette so as to be available during use.

Care in Handling Plates and Films.—In all cases, plates and films must be kept well protected by lead when in the x-ray room. A good lead-lined box on casters is very useful for this purpose, and where much work is done, one for exposed and another for unexposed plates should be pro-

vided, or a partition plainly marked "EXPOSED" and "UNEXPOSED," dividing a single box may be used.

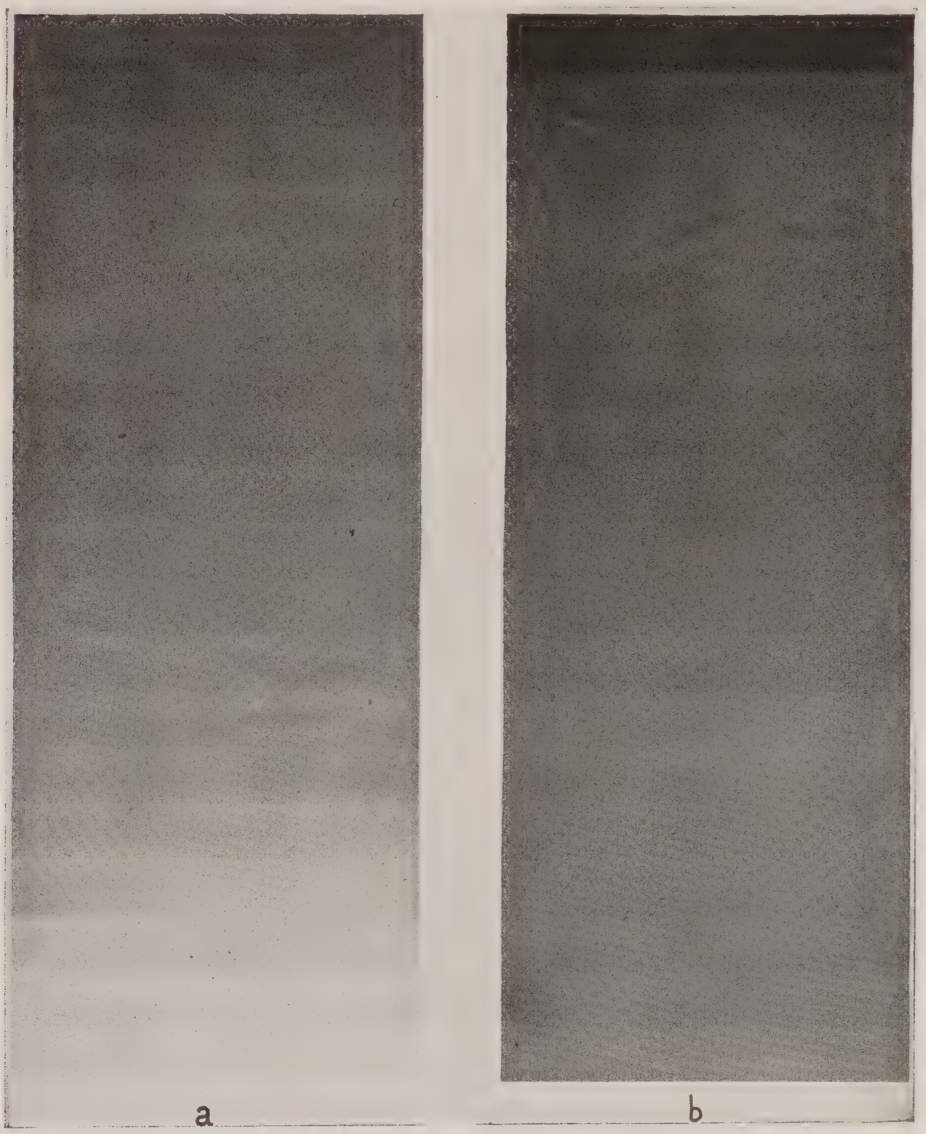


FIG. 52. Gradation due to successive equal exposures with and without intensifying screen, *a*, without screen, *b*, with screen.

The following cautions may be given to those unfamiliar with darkroom work:

1. Never handle plates or films with wet or greasy fin-

gers, either before or after exposure. Marks and streaks are sure to result, even if the emulsion is not destroyed.

2. Learn to handle plates without touching the emulsion side, even with dry fingers.

3. Mix all solutions according to instructions and see that chemicals are actually *dissolved.*

4. Keep all trays *clean,* and do not use insufficient or too old developer; stains are hard to remove, and the cost in time and money is excessive if it is attempted.

5. In tray development, be sure that the developer covers the entire plate at once. Tilt the tray slightly on inserting the plate, and tilt the tray in several directions to ensure complete wetting of the film as soon as possible. Keep tray in motion during development.

6. Do not examine the plate by removing it from the developer until the minimum time for full development on normal exposure has elapsed.

7. Do not try to develop several plates in a tray at one time if they overlap.

8. Wash negatives well on removing from the developer, before placing in the fixing bath.

9. Leave negatives in the fixer for some minutes *after* they *seem* to be fully cleared; then wash thoroughly, in running water if possible.

10. Do not use the same trays for hypo and for development. Mark hypo trays and keep them well away from developer. A little hypo in the developer is fatal.

11. Keep negatives in a dust-free atmosphere and in one location and position until dry.

12. When the developer is not in use, keep in *tightly* closed containers. Glass fruit jars with rubbers are as good as anything for small amounts. Use a close-fitting float in tank.

13. Don't try all the developing formulæ you can find;

take one advised for the plate you use, and learn to use it.

14. Don't fix in plain hypo in warm weather. Plates will frill if you do.

Tank Development.—In tank development, the plate is placed, while dry, in a special frame or holder and hung vertically in the tank containing the developer. This method is desirable when much work is done. With strong developer, stirring by moving the holders will prevent vertical streaks.

Temperature.—The action of the developer varies greatly with changes in temperature. Between 60° F. (16° C.) and 70° F. (22° C.) is best. Hot developer works *fast* and is likely to fog the plate. Cold developer is slow and may not give anything on a normal exposure. Do *not* cool developer by *adding* ice or ice water, as this dilutes the solution. When using tanks, cold or ice water may flow or stand around the developer tank until a proper temperature is reached, or put ice in a fruit jar and immerse jar in developer.

Concentration.—If more water is added to a normal developer, slower action will result. This is sometimes advised in tank development, and with screen plates, but is not necessary if the developer is stirred occasionally.

Plate Defects.—Plates are sometimes defective, due to faults or accidents in manufacture, but in most cases of complaint the trouble is due to improper treatment after leaving the factory. If one is sure of proper exposure, development, fixation and washing, and still finds streaks, spots, bubbles, or bad color, the plates may be blamed. Much trouble is traced to the materials used at present, and in all cases of doubt check plates should be made. Defects are not likely to appear on the same region in both negatives. Looking across the negative at any unevenly illuminated surface will often show whether a spot

is due to a defect in the glass or to something on the emulsion surface.

Examining Negatives.—When it can be avoided, plates ought not to be examined until dry. If they must be used while wet, care is needed to avoid heating the gelatin or it will melt and completely ruin the negative. A well-diffused illumination is very desirable; it should be well under control so as to give a strong light for dark negatives and a much weaker one for thin ones. Ground or opalescent glass is not needed if a dull white surface is illuminated and the plates are viewed by light reflected from it. Fig. 53 shows a useful type of illuminator.

Developer Action.—The action of developer on an exposed plate is rather a complicated matter. For the present purpose we may omit discussion further than to say that with any active developing agent a suitable amount of alkali is indispensable. Do not vary the proportion shown in reliable and tested formulæ, at least in routine work. Development at any given depth below the surface of the emulsion can only take place when the active developing solution has reached that point in sufficient amount to cause the change required. Hence, dilute or partly exhausted developer requires more time. Prolonged action of developer on the emulsion will cause a darkening even with little or no exposure, and too strong developer will over-develop the outer layers before the deeper ones are affected. Plates exposed to x-rays are developable through the entire depth of emulsion, while light only affects the outer layer. Hence, if fog can be avoided, x-ray plates will increase in density with longer development to a greater extent than will negatives exposed to light. The action of potassium bromide restrains or delays development at the surface and tends to keep the "whites" clear. All developers are absorbers of oxygen and are useless when

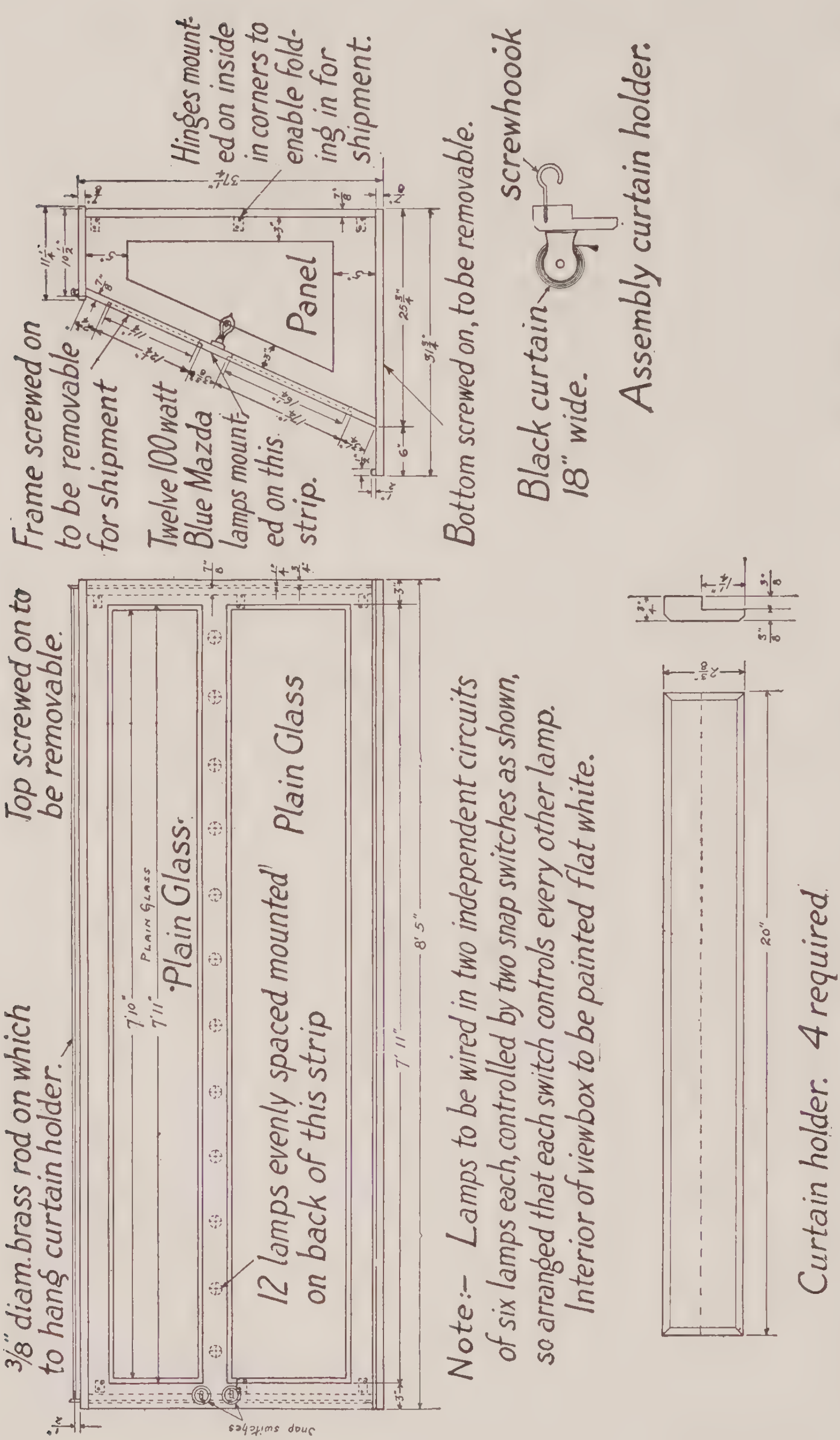


FIG. 53. Viewing screen. This viewing screen can be made in any desired length. It can be mounted on a plate-filing cabinet or on saw horse. Ventilator holes are provided to prevent excessive heat. It is so constructed that it can be readily knocked down for shipment.

they no longer absorb this gas. For this reason, they ought to be protected from air when not in use.

"Hypo" or Fixing.—The purpose of fixation is the removal of all unreduced silver, leaving the small specks of metallic silver suspended in the gelatin film. Any unreduced silver left in the gelatin will sooner or later discolor and ruin the negative. By using acid and alum, the clearing is improved and the film of gelatin hardened. "Hypo" must be *thoroughly* removed by washing half an hour to one hour in running water, so that hypo crystals will not form in the gelatin, ruining the negative. If the bath is too acid a rash will appear on the surface of the gelatin. The acid should be partly neutralized by the addition of sodium carbonate. If the bath appears milky, it generally lacks acid and can be cleared by the addition of acetic acid.

Fog.—It is extremely important for every roentgenologist to realize the full effect of fog produced on the negative in development. This fog is the result of chemical action and is always produced to a certain extent. It is not uniformly distributed over the plate in any case, and is related to a certain extent to the exposure at the points where it shows. It has, always, the effect of blotting out the finer details. In a properly exposed and developed plate these finer details show as light areas against a slightly darkened background, as, for example, in the case of a mastoid plate.

As soon as fog is produced to such an extent that these clear white lines become smoky, contrast with the slightly darker background and adjacent areas may be entirely lost. Fog will always be produced if the developer is too warm, if improperly mixed, or if the time of development is too long. The only way to avoid it for a given plate is to use a proper concentration of the developer, a proper tem-

perature, and such an exposure as will enable complete development to be made before fogging action becomes effective.

The roentgenologist should invariably remember that a proper distribution of shadows on his plate or fluoroscopic screen furnishes the only physical basis for diagnostic use of his radiation, and to avoid the necessity of passing upon indefinite and unsatisfactory plates it is just as essential to pay attention to the darkroom conditions as it is to consider proper position and exposure. The diagnoses made on the basis of shadows that are so faint as to be invisible to the majority of observers introduce a very considerable element of imagination, and are relatively unsafe even for those who claim successful results on such a basis.

Developing Formulæ.—Most x-ray operators had been using a hydrochinon-metol developer prior to the shortage of metol. Certain substitutes for metol have been marketed of more or less value. The following formulæ have been found fairly good in practice:

Hydrochinone—

Water (warm)	1	gal.	5	gal.
Sodium sulphite (dry) ..	8	oz.	40	oz.
Hydrochinone	1½	"	7½	"
Sodium carbonate (dry)	8	"	40	"
Pot. bromide	1	dr.	5	dr.

Mix in order named.

Good for tank development.

Elon-Hydrochinone—

(Dissolve these chemicals in order named:)

Water	20 oz.
Elon	20 grs.
Sulphite of soda (dry)	1 oz.
Hydrochinone	80 grs.

Carbonate of soda (dry)	1 oz.
Potassium bromide	8 grs.

Good for tank development.

Edinol-Hydrochinone—

Solution A

Boiling distilled water	32 oz.
Sodium sulphite (dry)	6 oz.
Edinol	5 dr.
Hydrochinone	1 oz.
Potassium bromide	6 dr.

Solution B

Water	32 oz.
Potassium carbonate	2 oz.

Use one ounce of Solution A, one ounce of Solution B and two ounces of water. Develop 6 to 9 minutes.

Good for tray development.

Metabisulphite-Hydrochinone.—A professional photographer doing considerable x-ray development recommends the following developer as very satisfactory for general work:

Mix in order named.

Solution A

Water	200 oz.
Hydrochinone	4 oz.
Potassium metabisulphite	10 gr.
Potassium bromide	50 grs.

Solution B

Water	200 oz.
Sodium sulphite	1¼ lbs.
Caustic soda	2¼ oz.

These solutions keep well in stock. For use, mix in equal parts.

Fixing Bath Formulæ.—An acid hypo fixing bath may be prepared as follows:

Water	64 oz.
Hypo	16 oz.

When *fully dissolved* add the following hardening solution:

Water	5 oz.
Sulphite of soda	1 oz.
Acetic acid (28% pure)	3 oz.
Powdered alum	1 oz.

If preferred, 1 ounce of citric acid may be substituted for acetic.

This bath may be made up at any time in advance and may be used so long as it retains its strength, or is not sufficiently discolored by developer carried into it to stain the negatives.

Chrome Alum Fixing Bath.—This bath has good keeping qualities, fixes clean and remains clear after long continued use.

A

Pure water	96 oz.
Hypo	2 lbs.
Sulphite of soda	2 oz.

B

Pure water	32 oz.
Chrome alum	2 oz.
Sulphuric acid, C. P.	¼ oz.

Mix chemicals in order named.

When dissolved, slowly pour B into A while stirring rapidly.

Notes on Fixing.—Hypo is cheaper than spoiled plates. Use plenty and renew often. Wash all plates very thoroughly to remove hypo.

Do not strengthen an old weak hypo bath. Throw it away and make a new one. It may fix, but it is sure to spoil plates sooner or later.

Failure to wash off developer will quickly spoil a fixing bath.

Stained plates are usually due to one or more of the following causes:

Too warm developer.

Too long development of under-exposed plates.

Exhausted hypo bath.

Lack of acidity of the hypo bath.

Reducing Dense Negatives—

Solution No. 1

Water	16 oz.
Potassium ferricyanide	1 oz.

Solution No. 2

Water	16 oz.
Hypo	1 oz.

Place plate in a solution made up of two parts of Solution No. 2 and one part of Solution No. 1, sufficient to cover it and watch it carefully. If it reduces too slowly remove plate while adding more of Number One.

Wash in running water at least a half hour after reducing.

Note.—Make negative properly and avoid reduction.

Darkroom.—The first consideration in a darkroom is the complete exclusion of *ordinary* light. All windows, cracks, knot holes, key holes, etc., must be stopped by opaque material. If possible, an entrance by corridor or winding way should be used. If a door is used it should fasten on the *inside*, so that no one can open it at an inopportune time.

The usual emulsion on x-ray plates is quite insensitive to red or orange-red light. A very small intensity of blue or white light will ruin a plate. The quality of light, not the amount, is what must be considered, and enough of a safe light may be used to see clearly what one is doing without danger of fogging a plate, if the operator is not too slow. The inner walls of the room should be painted red or orange, not black. A ruby 20-watt lamp, four or five feet above the working shelf with a translucent shade below it covered with postoffice paper, will give a diffuse illumination of the room very desirable for

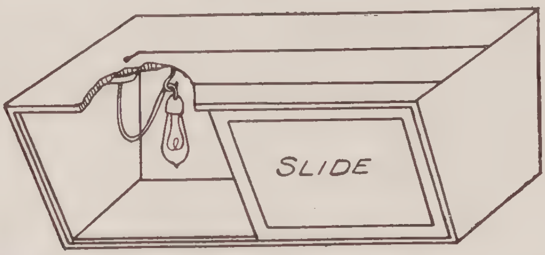


FIG. 54. Simple arrangement of light for developing. The slide contains a white and a ruby glass with yellow (P.O.) paper between. A clear lamp is used.

work. Test the light by placing an opaque object on a small plate. Expose on the shelf for two minutes and develop full time; if not fogged, the light is safe for that make of plate. If one desires to time development by looking *through* the plate, an arrangement as shown in Fig. 54 or one as sold by some dealers is desirable. By using a flexible cord, the lamp in Fig. 54 may be hung outside after the box is opened and serve as the source to be used when no plates are exposed to light.

Arrangement.—Darkrooms may be quite elaborate and yet be very inconvenient. A simple arrangement for a small outfit is shown in Fig. 55. No doors are needed in this case.

Fixing bath and supplies are to be kept apart from de-

veloper and developing supplies. A plain open shelf is used in filling envelopes, etc. Cassettes, intensifying screens, and envelopes may be kept in suitable compartments below. Plates in small amounts may be kept in compartments above this shelf. An inexpensive arrangement serving all

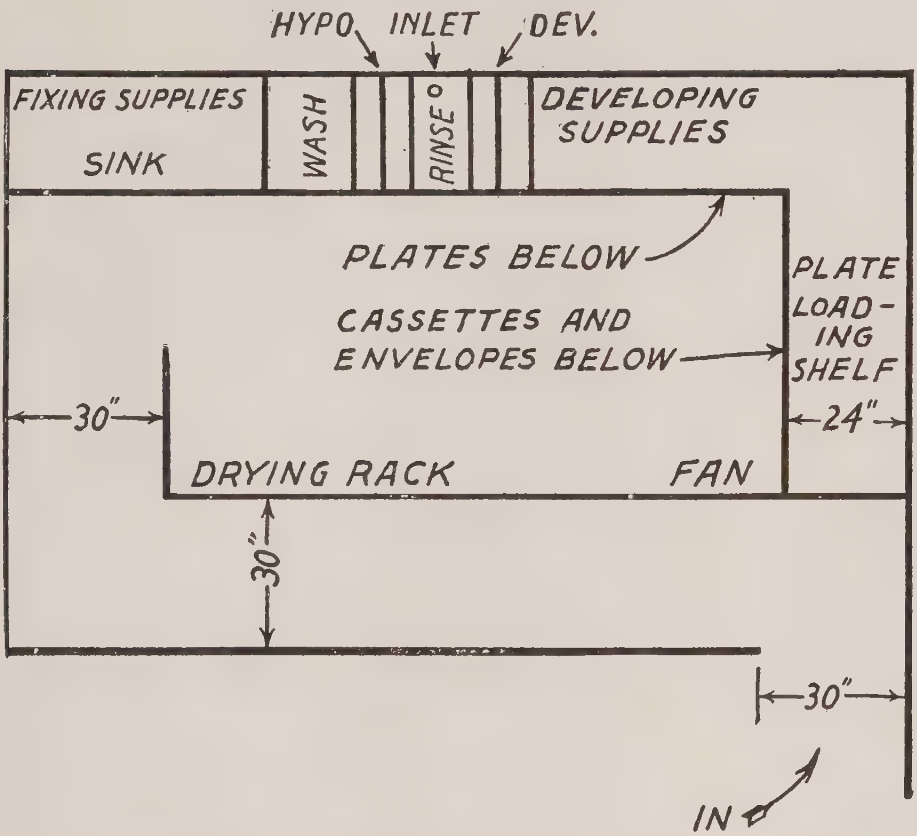


Fig. 55. A convenient darkroom arrangement.

needs is shown in Fig. 56 for holding developer tank, fixing tank, and also serving as a washing tank. For a permanent installation the tank may be lead-lined, but for a semipermanent wooden tank a heavy coating of water and chemical-proof paint will suffice. In warm weather, use ice to cool bath, and do not dilute developer.

Ventilation.—Good ventilation is essential in a darkroom, not alone to increase the efficiency of the operator,

but because a close, musty atmosphere is bad for the sensitive emulsion. When a new room is designed, the matter is quite simple, but when any old closet is regarded as good

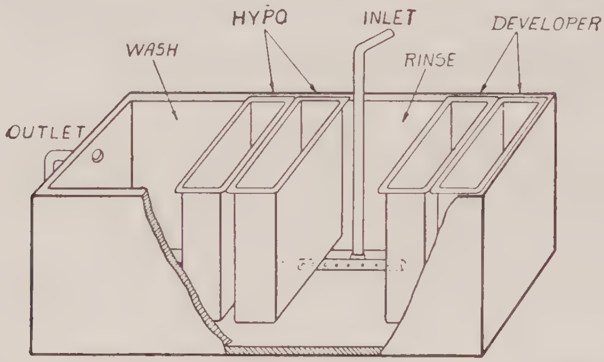


FIG. 56. Wooden tank to permit circulation of water around developer and fixer, provides for rinsing and washing films or plates at same temperature throughout.

enough for a darkroom it is quite a different matter. The important point to be kept in mind is that air must be let

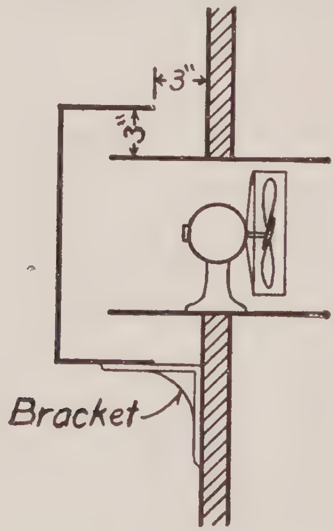


FIG. 57. Simple ventilator for darkroom. All inner surfaces to be painted red or black.

in and out, but light must be excluded. Where an electric fan can be used, it is easy to accomplish this result. Fig. 57 shows one way. The fan is placed in a box, open at each

end, inserted through the wall. A second box is placed inside the room, as shown, and all surfaces are painted a flat black. Air has free passage, and light is entirely excluded. A similar arrangement can be used in a window, either with or without the fan.

Humidity.—Basement darkrooms are often very damp in summer and very hot in winter. The best work cannot be expected under these conditions. If such must be used, it is best to keep unused plates elsewhere.

Care of Utensils.—Absolute cleanliness is essential in darkroom work. Trays not in use are best kept filled with water. Be sure that no acid gets into the developer. Do not use developer or fixing tanks painted inside with any kind of water-proof paint.

Supplies.—Be careful to keep all containers labeled, so that no mistakes are likely to be made. Keep hypo and acids away from developer material. Keep chemicals protected from moisture. Remember that twice the weight of crystals must be used as in case of "dry" materials.

Marking Negatives.—Where a large amount of radiographic work is done, a well-organized record system is indispensable. In all cases the record should show in some way on the negative, and that record must be put on *before* the plate is developed. Lead numbers may be used, and if this is done the number used and the name of the patient must *be entered on a suitable card or book at the time the exposure is made.*

If numbers are not used, a slip showing the name of the patient must be attached to the cassette or envelope, and the darkroom operator should always write the name with a soft pencil on one corner of the emulsion *before* development.

In using double-coated film care should be taken to mark right and left, as one cannot tell how the film was placed.

The X-Ray Negative.—The conditions which determine the distribution of shadows on an x-ray negative are extremely complex and vary with the physical condition, age, and weight of the patient even without any reference to pathological conditions. If there were no material between the target and the photographic emulsion, there would result, upon exposure and development, simply a uniform blackening of the plate. The introduction of material in the path of the radiation between the target and the plate results in absorption and scattering with the result that portions of the emulsion are protected from the radiation, the resulting shadow showing as a white or lighter area by transmitted light through the negative. The amount of radiation failing to reach any area of the plate as compared with that reaching the surface of the obstructing body depends upon two things: first upon the relative physical density of the material traversed as compared with its immediate surroundings and, second, upon the distance in this material of greater or lesser density actually traversed by the rays. As an illustration, the shadow cast by a thin, flat bone, placed with its surface parallel to the plate will show little contrast as compared with the shadow of the surrounding flesh, whereas, if placed on edge, increasing the path traversed in the bone, there will be marked contrast.

In traversing the human body radiation passes through an aggregate made up of portions of decidedly different densities. Each of these portions absorbs the radiation in an amount depending both on its density and thickness. When we further take into account the physical nature of the action of the photographic plate and the different absorbability of the radiation under different conditions of tube, we may easily recognize the reason for the variety of negatives which it is possible to secure of

the same anatomical region. Inasmuch as our diagnostic information must be acquired from a study of these areas, we must not forget that pathological conditions are liable to be inferred if based upon doubtful or imperfect data, and while we can not at present lay down complete rules for the guidance of the roentgenologist it is undoubtedly true that for each individual area there is a combination of factors of exposure, penetration, development, and position, that would give the best diagnostic plate.

Consider the effect of varying (1) the quality of the x-ray beam, (2) the time of exposure when making a negative of any particular region. Assuming that we have proper development of the plate after exposure, we may note that if the tube has a small equivalent gap the majority of the radiation will be absorbed completely by even thin and non-dense portions of the patient, and that the exposure in order to have any effect on the plate must be prolonged. For example, in the case of the hand, such a tube with proper exposure may bring out wrinkles or folds in the flesh, finger nails, and a very slight infiltration in the soft tissues, and only by prolonged exposure can even a moderate definition of bones be observed. When this is done the parts of the negative covered by soft tissue are greatly overexposed. If the spark gap is too small nothing but a shadow of the hand such as would be cast by ordinary light will be observed. As we change the spark gap with a suitable time of exposure we can secure quite different qualities of negative and, with a moderate gap and exposure, fair details in the bone and the soft tissue may be observed, but, with longer exposure, portions of the plate beneath the thinner or softer regions still become overexposed, giving, on development, complete blackness without details. At the same time the outlines of the thicker portions and of the

bones may stand out very clearly, giving almost the appearance of a skeleton.

If the spark gap is made too high the radiation reaching the plate may be only modified to a slightly greater extent by the bones than by the soft tissue, and we get a characteristic plate, lacking in contrast, which is generally described by the term "flat." In an extreme case, nearly all of the radiation might pass through the body with only a trifling amount of absorption, and there would be no differentiation with reference to density and thickness upon the plate. Consequently, while no complete guide can be given, the general effect of increased spark gap is to reduce the contrast, and the general effect of increased exposure with moderate gap is to obliterate the details in the soft tissue or thin portions with an increase in the visibility of the shadows cast by the denser or thicker portions. If, for example, one desires a study of the thoracic vertebræ, one must expect that portions of the plate receiving radiation through the air-filled lungs will be greatly overexposed and will indicate no shadows. With a softer tube, details of the spine and ribs will be less obvious, while the linear markings in the chest are rendered visible. It naturally follows that tube condition and exposure should be adapted to bring out the information desired. Mention may also be made of the fact that the overexposed and denser regions may frequently give valuable information if viewed with a sufficiently strong source of light, while a thin negative, or those portions in which the shadows are faint and the total blackening slight, are best observed in weak light.

Inference as to pathology can only be safely made when due account is taken of the variation in the shadows due to normal variation in human anatomy and the procedure followed in making the negative.

Form 551
MEDICAL DEPARTMENT, U. S. ARMY
(Revised July 19, 1917)

CLINICAL RECORD
RADIOGRAPHIC REPORT

Station..........
Date.........., 191
From..........
To..........
....

Information requested:..........
....
....

Clinical diagnosis:..........
....
....
....
.........., *U. S. Army.*

Laboratory..........
.........., 191

X-ray findings:

PLATE

NUMBER	SIZE	PART	DISPOSITION

....
.........., *U. S. Army.*

SURNAME OF PATIENT	CHRISTIAN NAME

RANK	COMPANY	REGIMENT OR STAFF CORPS

FIG. 58. Record and report form for x-ray examination (actual size $3\frac{1}{2}$ ins. x 8 ins.).

Records.—The importance of the correct *recording* of all information obtained by means of the x-ray cannot be overestimated. Of equal or greater importance is the establishment of the identity of the patient examined with the x-ray findings. Furthermore, the identity of the *side* examined should be verified in every case.

That the x-ray findings are brought to the attention of the attending surgeon is essential. An actual conference between the surgeon and the roentgenologist is very desirable in order that each may have the advantage of the other's personal opinion.

Each plate should, therefore, be marked for identification by means of opaque markers and the corresponding information immediately recorded on the blanks provided for this purpose.

Form 551 Medical Department, U. S. Army (Revised July 19, 1917), will be used for this purpose, Fig. 58. In all cases a duplicate of this report should be retained.

LABORATORY EXPERIMENTS

Laboratory Instruction in Preparation for Roentgenology.—The following experiments are part of a series used in the laboratory course. They were easier of execution in the laboratory in which they were devised, and results were more conclusive, on account of having a very good high tension voltmeter so that tube voltage measurements could be accurately and quickly made.

The objects of such experiments are:

1. To give practice in quickly adjusting machine and tubes to any desired current and voltage.

2. To impress on the mind of the student the relation of the fundamental factors—voltage, current, distance and time—to the nature of image desired.

3. To assure the operator that results are reproducible if conditions are right.

4. To show some of the pitfalls usually encountered and to avoid having to acquire experience on the living patient.

While at first such experiments may seem very time-consuming, experience has shown that the skill and confidence acquired will much more than repay it in a comparatively short time.

New students, and even those of some experience, are likely to have trouble in handling the apparatus if it has many unusual details. They should, therefore, read such paragraphs of the manual as deal with the elementary principles, before starting experimental work.

The Coolidge tube is used in these experiments on account of its easy adjustment. Experience indicates that when taking the *same current* at the *same voltage* all tubes give very much the same density of negatives, so that exposures learned on the Coolidge tube apply to the gas tube in so far as the conditions can be made the same.

Experience in the training of a considerable number of students has clearly shown that the handling of x-ray apparatus *cannot be learned by seeing some one else do it.* Only when the students have repeatedly carried on the actual manipulations themselves, time after time, can they be depended upon under working pressure. Much time is lost in not knowing just what exposures should be given and the test plates described are excellent checks on accuracy and rapidity. The student should be well drilled in quickly setting the tube and control for definite readings. In the study of plates as well as in the technical work the student should do *absolutely individual and independent work.*

Instruction Unit.—A small instruction unit has been devised to clearly set forth the basic principles of the large x-ray machines and to avoid unnecessarily tieing up expensive equipment for elementary instruction purposes. This machine is composed of only the customary elements and these are arranged on an ordinary pine table so that all parts and all wires are completely in view and readily accessible. For instruction purposes high power is unnecessary, and a small transformer is ample for the purpose. With the transformer used, loads up to 5-inch gap, 30 ma., may be safely drawn for test plate and other experimental work. The autotransformer, rheostat, filament transformer, timer, etc., are standard parts as used on the large machines, so that the student may become familiar with their function and operation.

It is intended to have the machine as simple as it is possible to make it, and to this end the various circuits are distinguished from each other by the color of wire used. Thus, the main primary circuit is black, the motor circuit is blue, the Coolidge filament primary is red, and the remote control circuit is green. Even to a beginning student the circuits stand out separate and distinct, and the machine appears organized and rational rather than

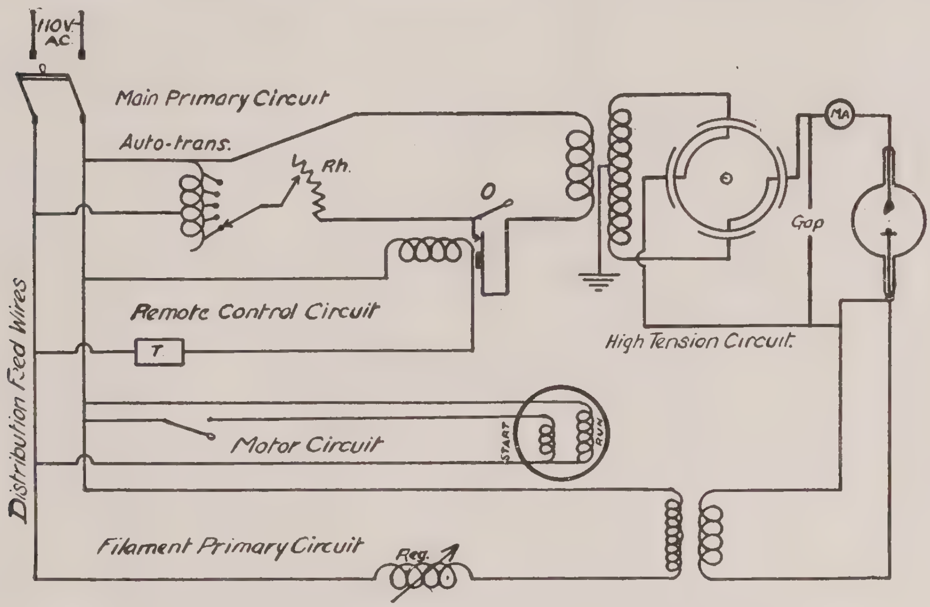


FIG. 59. Diagram of connections of instruction unit.

a hopeless maze of wiring. Fig. 59 shows the diagram of connections and Fig. 60 shows the machine itself. Superfluous parts have been eliminated and the features shown are so fundamental that each student should be able to wire up the complete machine as part of his laboratory work.

Aside from giving a knowledge of the electrical elements of x-ray machines, the unit is used to give considerable practice in setting for any desired tube voltage and milliamperage, in operating when failure of some non-essential

element occurs, and in studying the physical properties of the x-rays.

Test Plates.—The quantitative measurement of x-ray radiation has proved a difficult matter, but for our pur-

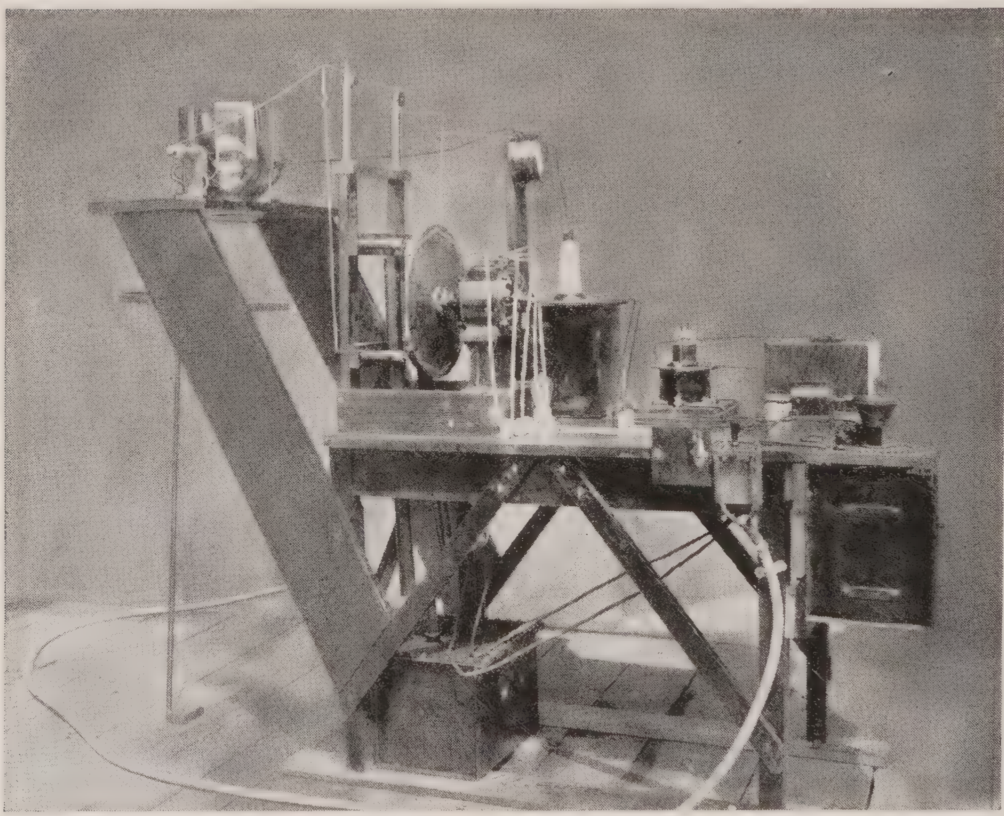


FIG. 60. Machine used for instruction purposes. All parts and wiring are openly displayed.

pose the photographic effect is sufficiently accurate and determines the usefulness of the rays in practice.

We cannot readily compare the radiation received on two spots of unequal density. Under any conditions of operation, however, if two portions of a photographic plate subjected to radiation and given the same develop-

ment have equivalent blackening we may say that the two parts *received the same quantity of photographically effective radiation* per unit area, or that they *had the same exposure,* in which case exposure does not mean time alone.

If a spot exposed 1 second and a spot exposed 2 seconds are of equal darkness, then we can say that the first spot was subjected to radiation twice as intense as the second, for it took only half as long to give equal effect. The spots should not be heavily overexposed or over-developed, for it is in the medium gray tones that distinctions in density are most accurately and easily made.

A 5 x 7 plate is cased in the usual envelope or in a light-tight plate holder. The student's name, laboratory number and the number of the experiment should be written on the emulsion side of the plate with soft lead pencil when loading. A 5 x 7 lead plate with ten 1-inch holes is used to protect the body of the plate from radiation and all holes except the one spot to be exposed are covered with sheet lead. Expose the test spots in proper sequence down the two rows of holes, and place a small metallic marker on spot No. 1 during exposure to identify it later.

In using a timer do not vary its settings, as the scales are rarely calibrated with sufficient accuracy. Keep the timer set at 0.1 second and repeat the exposure the required number of times. If the machine is not equipped with a timer capable of conveniently repeating 1/10 second exposures, time with a stop watch or by counting to full seconds instead of tenths. Increase considerably the target-plate distance in this case, if possible.

Do not develop test plates too far. Stop as soon as

spots Nos. 1 to 5 show fairly well on the back of the plate. If the settings have been carefully made and exposures accurately timed, spots Nos. 1 to 5 should be approximately equal in density and Nos. 6 to 10 should run successively darker or lighter as the case may be.

When the finished plates are dry the spots should be numbered and all exposure data written on the emulsion side of the plate with pen and ink. The plate should then be turned in for inspection and credit.

Before commencing work read and understand the general instructions and precautions on page 20.

Distance-Time Relation—Inverse Square Law.

Test Plate 1.—The x-rays travel out from the electron impact point on the target in straight lines, so that the amount in a cone of a given angle is spread over an increasing base area as we recede from the tube. A plate of fixed size intercepts more radiation in a given time when close to the source. If we move a plate to double its original distance from the target, the radiation received per second on a given area will be only ¼ as great; at ten times the distance, 1/100 as great. In order to secure the same radiation effect, the time of reception must be increased four-fold in the first case and one hundred fold in the latter.

For *constant tube current and voltage* the plate blackening will be unchanged if we keep $\frac{\text{time}}{\text{distance}^2}$ constant for all exposures.

Set for 10 ma. at a 3-inch spark gap and expose spots as shown below. Or the bedside unit may be used, exposing seconds instead of tenths.

Spot No.	Distance	Time	Spot No.	Distance	Time
1	10 in.	.1 sec.	6	10 in.	.1 sec.
2	20 "	.4 "	7	20 "	.1 "
3	30 "	.9 "	8	30 "	.1 "
4	40 "	1.6 "	9	40 "	.1 "
5	50 "	2.5 "	10	50 "	.1 "

In the first row of spots we have compensated for the change in distance by a proper corresponding change in time, so these spots will have the same density. In the second row we have made no such compensation and the spots will not be equally dark. The target-plate distances ordinarily used in radiographic work vary from 15 to 36 inches. The sharpness of the radiograph increases with greater distance, but longer time is required. Assuming that 1 second is the correct exposure for a given object at 20 inches, plot a curve on cross section paper showing time required at various distances up to 36 inches to give the same density of plate.

Current-Time Relation.

Test Plate 2.—The x-ray energy on a given plate area per unit time when the voltage is constant and the target-plate distance is fixed, increases in direct proportion to the current. Thus, we get the same radiation in *half* the time when using 50 ma. as when using 25 ma. Or, for equal photographic effect the product of milliamperes and seconds must remain constant.

To test this law expose a test plate as follows:

Voltage constant at a 4-inch gap.

Target-plate distance constant at 30 inches.

Spot	Current	Time	Spot	Current	Time
1	5 ma.	1.2 sec.	6	5 ma.	1.2 sec.
2	10 "	.6 "	7	10 "	1.2 "
3	15 "	.4 "	8	15 "	1.2 "
4	20 "	.3 "	9	20 "	1.2 "
5	30 "	.2 "	10	30 "	1.2 "

Notice that we have compensated by a decrease in time for the increase in current in the first row and that the second row is uncompensated.

Voltage-Time Relation.

Test Plate 3.—The radiation leaving a given target as registered by a photographic plate is not fixed by the amount of current alone, but varies greatly with the drop in voltage through the tube. In fact, it increases very nearly in proportion to the *square* of the voltage. This means that on doubling the voltage, all other factors remaining unchanged, we get four times the photographically effective radiation per second and would then need but *one-fourth* the exposure time.

With an electrostatic high tension voltmeter it is easy to read voltage directly, but this instrument is not ordinarily available. The so-called primary "kilovoltmeters" with which many machines are equipped are not reliable indicators of secondary voltage, as they do not read the same for the same secondary voltage under different loads on the transformer. Parallel sparking distance between blunt points is our best available guide to tube voltage. The relation between spark length and kilovolts is shown in Fig. 12. It may be considered as reasonably true that

under average conditions the kilovoltage is ten times the spark in inches plus ten, i. e., 3-inch gap = 40 kv.; 5½-inch gap = 65 kv., etc.

Exposures are to be made as follows:

Current constant at 5 ma.

Distance constant at 25 inches.

Spot	Gap	Time	Spot	Gap	Time
1	2″ (30 kv.)	1.6 sec.	6	2″ (30 kv.)	1.6 sec.
2	3″ (40 ")	.9 "	7	3″ (40 ")	1.6 "
3	4″ (50 ")	.6* "	8	4″ (50 ")	1.6 "
4	5″ (60 ")	.4 "	9	5″ (60 ")	1.6 "
5	6″ (70 ")	.3* "	10	6″ (70 ")	1.6 "

* These figures are fair approximations to the exact values.

The equality of density of numbers 1 to 5 as well as the great density difference of numbers 6 to 10 illustrate well the effect of increased voltage.

It must not be assumed that the quantity of radiation alone varies with the voltage at constant current and time. The ability to pass through material also increases to a great extent at higher voltage. The quality of negatives of the same average density made at high and at low voltage is quite different and a voltage (penetration) suitable for the case in hand should be chosen if the best results are to be secured.

Summary of the Preceding Relations

Test Plate 4.—Formulating the experience derived from the preceding experiments, we may conclude that for a given tube and machine—i. e., a fixed wave form, frequency, target, and absorbing glass wall—we may regulate

the exposure, when no absorbing material is traversed, by control of (a) current, (b) voltage, (c) time, (d) distance.

Expressed in algebraic form, the photographic effect E is given by

$$E = \frac{K \text{ x Current x (Voltage)}^2 \text{ x Time}}{(\text{Distance})^2}$$

where K may change for various targets, glass walls, or wave form, but is fixed for a given tube and outfit. If this is true, one can readily compute from *one* set of conditions the length of time under other conditions that will give the same plate density.

To calculate the time for a given exposure use simple approximate methods, not long and involved computations. Thus, if a case is given as follows:

Exposure 1:

50 ma.—5-inch gap—18 inches—4 seconds.

Exposure 2:

15 ma.—4-inch gap—27 inches—time = ?

Decrease in current increases time 10/3 times.
Increase in distance increases time 9/4 times.
Decrease in gap increases time 25/16 = 3/2
Then the required time is

$$\cancel{4} \text{ x } \frac{\overset{5}{\cancel{10}}}{\cancel{3}} \text{ x } \frac{9}{\cancel{4}} \text{ x } \frac{\cancel{3}}{\cancel{2}} = 45 \text{ seconds.}$$

Start with 4-inch gap 10 ma. 20-inch target-plate distance, and .2 sec. Calculate and expose 11 spots so as to vary two or three of the above factors each time, but keep E constant. $E = \frac{(4)^2 \text{ x } 10 \text{ x } .2}{(20)^2} = .08$ arbitrary units for spot

No. 1. Thus, if current is raised to 30 ma., this increase would give a time ⅓ as great; but if the distance is raised to 30 inches the greater distance would require a time 9/4 as great. Hence the correct time with the combined change is .2 x ⅓ x 9/4 = .15.

Do not work below a 2-inch gap on account of the absorption of the glass walls of the tube, or on the small instruction units above 5 ma. on a 6-inch gap or above 30 ma. on a smaller gap.

Use a variety of control buttons, and where the timer will not give exact results, get as near as possible or vary one or more factors to get exact tenths. The timer will not give smaller fractions with any considerable accuracy.

The exposures are to be computed before coming to the laboratory.

Enter your results as follows:

No,	MA.	Gap.	Distance	Time
1	10	4″	20″	.2 sec.
2	5	5″	25″	?
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

If correctly done, no variation in darkening will be observed.

Change in Time of Exposure with Thickness

Test Plate 5.—Exposure Factor. Find by trial the ratio of the time required to get the same density through *one* layer of a paraffin as when no absorber is present. To do this, expose a plate, using a machine setting of 10 ma., 3-inch gap; or use the bedside unit, exposing seconds instead of tenths and giving the plate much shorter development. Use 17-inch distance for all spots.

Spot No.	Layers of Paraffin	Time	Spot. No.	Layers of Paraffin	Time
1	0	.1	6	1	.4
2	0	.2	7	1	.5
3	0	.3	8	1	.6
4	1	.2	9	1	.7
5	1	.3	10	1	.8

When the plate is developed compare other spots with Nos. 1, 2 and 3, and select the pair that comes closest to an exact match in density. If, for example, spots No. 1 and 5 are equally dark, the exposure factor is determined by the ratio of the time of exposure used—in this instance, 3.

This factor can be checked by comparing spots No. 2 and 8, which should match if the factor is 3.

A method similar to this can be used to obtain the speed ratio of intensifying screens, exposing part of a plate with a screen and part without, as suggested elsewhere in the manual, Fig. 52, page 114.

Absorption of rays and scattering gives an explanation of the great increase in time of exposure with increasing

thickness of absorbing layer. Thus, if experiment shows that a certain thickness of a given material will reduce the emerging radiation to 3/5 the incident, then a spot exposed through this layer will require 5/3 the time for the same photographic density as the uncovered portion of the plate would require. For two such layers 25/9 the original time will be required, for three layers 125/27, etc.

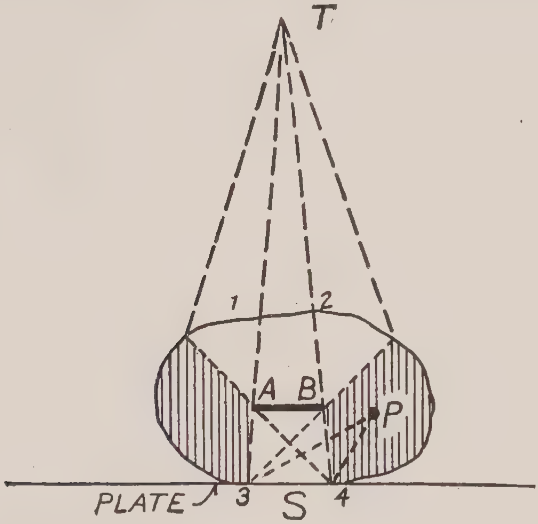


FIG. 61. Effect of scattering on undercutting of image.

(*Test Plate 6*). Using the factor obtained from Test Plate 5 and the law indicated above, calculate proper exposure times and expose the plate as follows:

Machine setting constant at 10 ma., 3-inch gap, 30-inch distance; or use the bedside unit, if it was used for Test Plate 5, again exposing seconds instead of tenths and giving the plate short development.

Spot No.	Layer of Paraffin	Time	Spot No.	Layer of Paraffin	Time
1	0	.3	6	0	.3
2	1	..	7	1	.3
3	2	..	8	2	.3
4	3	..	9	3	.3
5	4	..	10	4	.3

The time for proper exposure in order to get the best plate does not work out from the simple law of absorption. The reason is clear when we consider scattering in tissue. Let *AB*, in Fig. 61, be a small object in the body, relatively opaque to x-rays. If there were no scattering, the area *S* would be protected from radiation by an amount fixed by the *increase* in absorption of *AB* over that of an equal amount of tissue. Thus, if volume represented by 1, 2, 3, 4 would absorb 95 per cent when *AB* is absent, then if the object were *entirely* opaque it could only reduce exposure by 5 per cent of that adjacent to it. In addition, all the shaded portions of the figure are sending scattered radiation to *S* in proportion to what each point receives. To reduce this scattering as much as possible no more of the body should be exposed than is necessary, and conditions maintained to give as high contrast as possible. The best plates of thick parts are rarely of high density as compared with those of extremities. Contrast is always better when the gap is made as low as possible, consistent with other operating conditions.

The Benoist Penetrometer

Test Plate 7.—X-rays are caused by the violent change in the speed of electrons, and the quantity and quality of the beam will depend on the number of electrons involved, their speed, and the suddenness of their stop. By quality, we should specify the relative intensity of each wave length. As the operating voltage is increased, there is a great increase in the electron velocity. Thus $Ev = \frac{1}{2} MV^2$, where E is the electronic charge, v the voltage, M the mass of the electron, and V its speed.

There is no way of easily analyzing a beam and so the ability of the shorter waves to pass through material is used to give a rough idea of the quality. This penetration is only approximately indicated by a penetrometer. The Benoist penetrometer may be used to test out exposures and to secure a more accurate knowledge of the factors governing plate density than can be easily acquired otherwise.

Use a lead cover having twelve holes to take a fairly large penetrometer. Use sheet lead to cover parts of plates not being exposed. Remove the holder from the table and cover all portions while adjustments are made, in order to avoid fogging. Take considerable care in adjusting the tube, and note carefully the exposures specified. Study your plate and see how it checks out with the computed times for equality of density as far as the blackening under the silver is concerned.

Silver is approximately a non-selective absorber for the range of wave lengths used in practice, while the aluminum absorbs "soft" rays in excess. Read the "hardness" by noting the number of the aluminum sector that gives the same photographic density as the silver. That sector giving the highest plate density is called No. 1, and the others number consecutively. Discuss carefully the difference seen in the negative. Make the following exposures with fairly careful settings.

Target-plate distance, 15 inches.

Row 1			Row 2			Row 3		
Ma.	Gap	Time	Ma.	Gap	Time	Ma.	Gap	Time
10	2″	1.2	10	2″	1.2	10	2″	1.2
15	2″	.8	10	3″	.7	15	3″	.4
20	2″	.6	10	4″	.4	20	4″	.2
25	2″	.5	10	5″	.3	25	5″	.1

Tabulate the Benoist hardness and voltmeter readings, also plot on cross section paper. What relation exists in the incident radiation among the above exposures?

The *longer* wave lengths are absorbed in excess, and the remainder of the beam as transmitted contains an excess of short waves. Such a beam is said to be filtered.

NOTE.—The Benoist penetrometer is not a very useful or reliable guide as to tube quality—not nearly so satisfactory in transformer operation as spark gap; but it does serve to give an idea of penetration difference if one is sure that the same *quantity* falls on the instrument in each case.

NEW APPARATUS

In the following pages of this manual there will be described some new apparatus and appliances which have been developed with advice of many roentgenologists and surgeons with the sole intent of aiding the service. This apparatus was not designed to secure novelty, or simply to be different from other devices, but with a view of securing, first, simplicity and convenience, second, elimination of error and unnecessary steps and, third, to secure manufacture at such a rate as will enable the product to be used at the earliest possible moment.

It is urgently desired that every roentgenologist to whom this apparatus is delivered take the time necessary to study it over and to acquire, at least initially, the point of view of the designer. Simply because some particular feature with which he has been familiar, and which has been more or less fashionable among roentgenologists, is missing, is not a sufficient excuse for general condemnation or rejection of the standard outfit. After making sure that the apparatus is properly assembled every operator should go rapidly through the steps in handling it with a view to smoother operation and to saving time. The instructions which are given may serve as a basis for such self-drill, and it is of course to be expected that many modifications of procedure and inexpensive additions to equipment may readily be provided on the initiative of the operating roentgenologist.

Every roentgenologist is advised to file and retain all copies of instructions and catalogues or blue prints fur-

nished with the outfit by the manufacturer. These may be of considerable assistance in case of breakdown or damage, even though the directions, in some measure, do not correspond with the general instructions given in this manual.

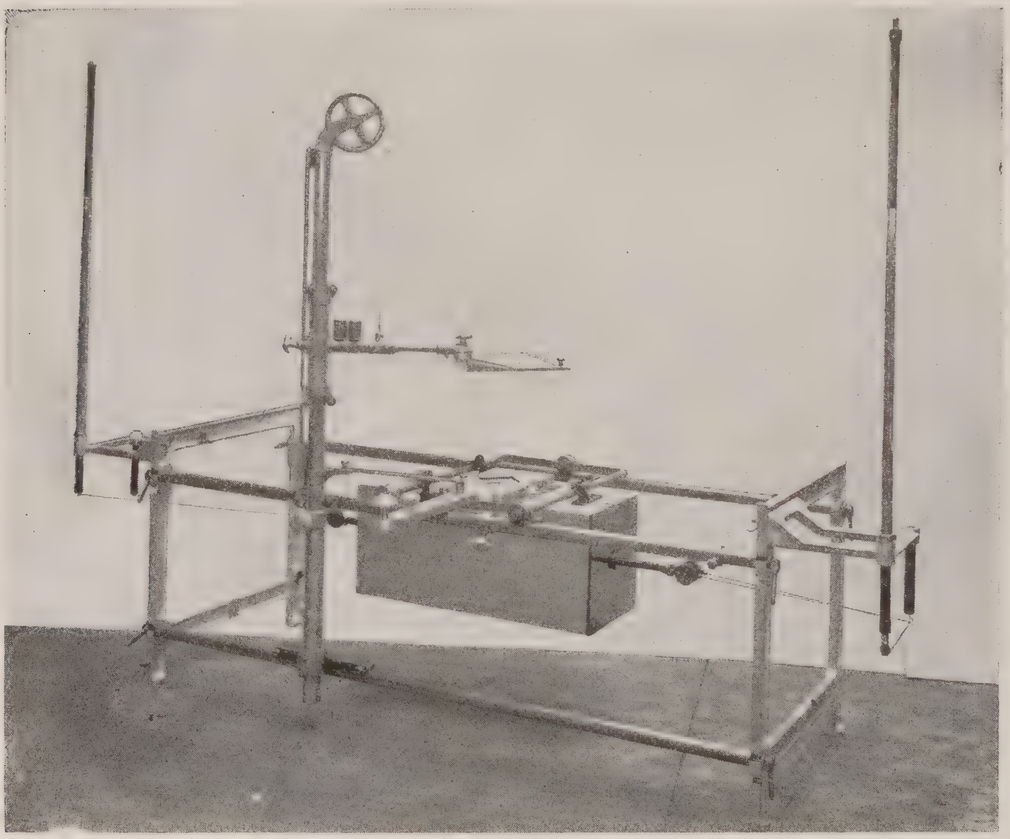


Fig. 62. Standard U. S. Army x-ray table with insulating masts and holders and box for standard type tube.

Army X-Ray Table.—The standard x-ray table consists of the following principal parts: (Figs. 62 and 63.)

1. Two aluminum end castings.
2. Three steel side rails.
3. A rectangular frame as a tube-box cradle.
4. A lead-covered tube box.
5. A special detachable shutter.

6. A rectangular wooden frame supporting a stretcher type top.
7. An operating switch.
8. A special screen carrier.
9. High tension vertical insulators.
10. A tube holder for working above the table.

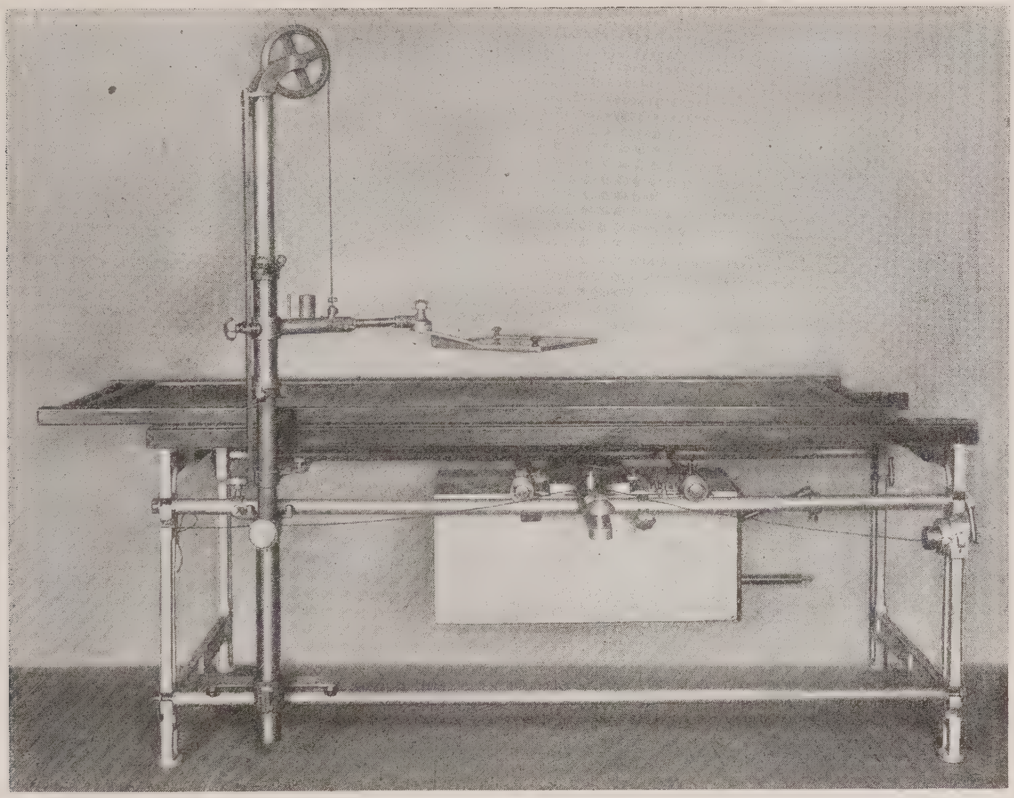


FIG. 63. Standard U. S. Army x-ray table complete with box for radiator type tube.

When the table is to be used with the portable outfit a tube box designed for the radiator type of tube must be used. For the usual base hospital outfit, a tube box taking the standard tubes is supplied. In the former the high tension insulators both enter the same end of the box, in the latter they enter at opposite ends. Any or all of numbers 8, 9, and 10 may be omitted in special cases.

In the description following, numbers in parenthesis refer to the figures in the text, *not* to manufacturers' stock or replacement numbers.

End Castings.—(Fig. 64) The end castings (41) have four slots (42) on each side. These take the ends of the steel side rails. *Two* rails (45) are used on the operator's side of the table and *one* on the other side. When using the regular top the rails should be placed in the

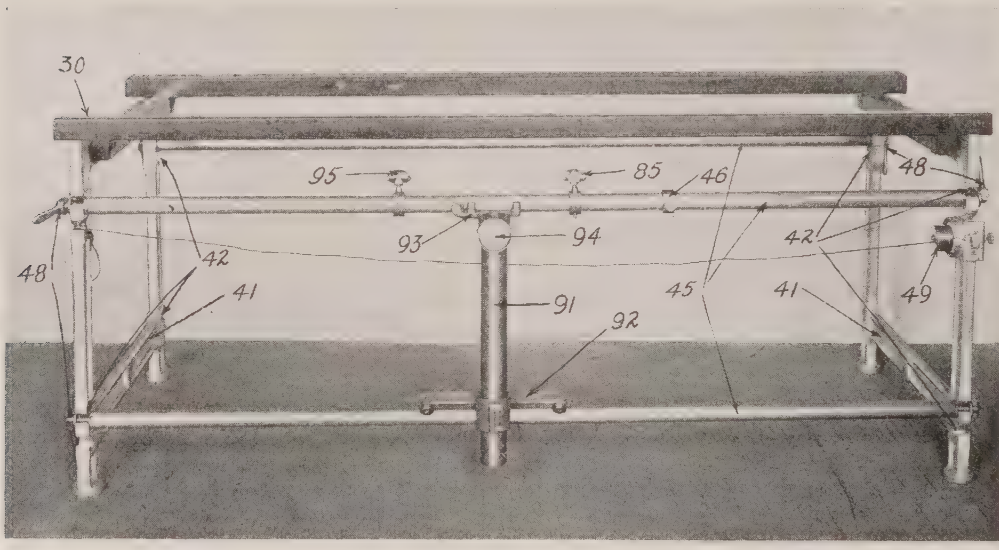


Fig. 64. Framework of standard army x-ray table and operating pull switch (49).

upper of each pair of slots. If one must use an army litter, use the lower slots. Holes are provided to mount the masts for overhead work.

Rails.—(Fig. 64) The round rails have tightening screws (48) with permanently attached handles. Sliding on one of these rails are three rings (46, 85, 95). The one at the left serves to lock the screen carriage, the center one locks the tube box against longitudinal run and also may be used to secure a tube shift of either 10 or 15 centimeters. The right-hand ring serves in measuring any desired tube

shift. These should always be placed on the rail in the order shown.

Cradle.—(Fig. 65) The cradle has three roller-bearing wheels (81) to give longitudinal run on the side rails. The single roller on the right has a screw brake to be used when lifting the box. The cross piece on the

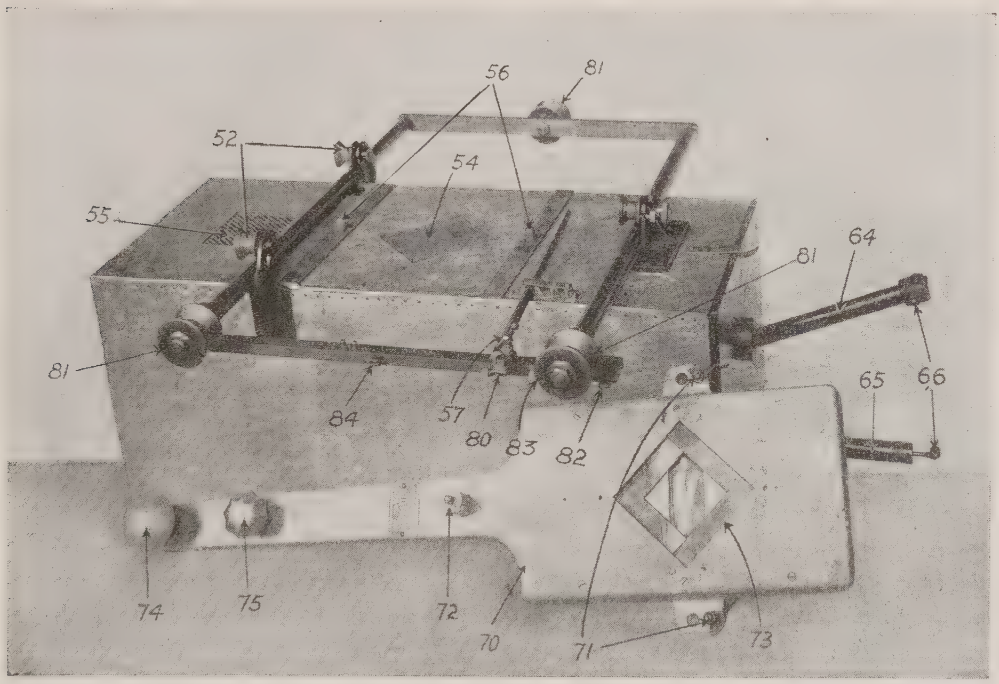


Fig. 65. Details of tube box, cradle and shutter, standard army x-ray table.

operator's side carries a tube box brake (57) for lateral locking when in use, also three stops for tube shift measurement. The one near the center (84) is permanently attached, as is also the one at the right (82). The third (83) is placed close to the roller and when the ring (85) is placed between (83) and (84) we have a 15 cm. shift; by changing the position of the screw (57) of the cross run brake, we may secure a 10 cm. shift between stop (84) and the stop (80) on the brake.

Box.—(Figs. 65, 66 and 67) Two types of box are built, one for use with the radiator type Coolidge tube, the other for the ordinary tubes. *The former must be used on all portable outfits,* the latter is known as the base hospital tube box. In the *portable box both insulators enter at one end.* In the base hospital one is placed at each end.

In both boxes the tube mount slides into the box at the end. Fig. 67 shows the mounting with insulators for the radiator type of tube. The partition (62-63) is covered with lead rubber and the upper portion is removable for insertion of the tube. The tube may be raised or lowered or shifted longitudinally for centering. The insulating posts with the transverse wire (69) are used in adjusting the target position. All connections to the tube are to be made *before* inserting the slide in the box.

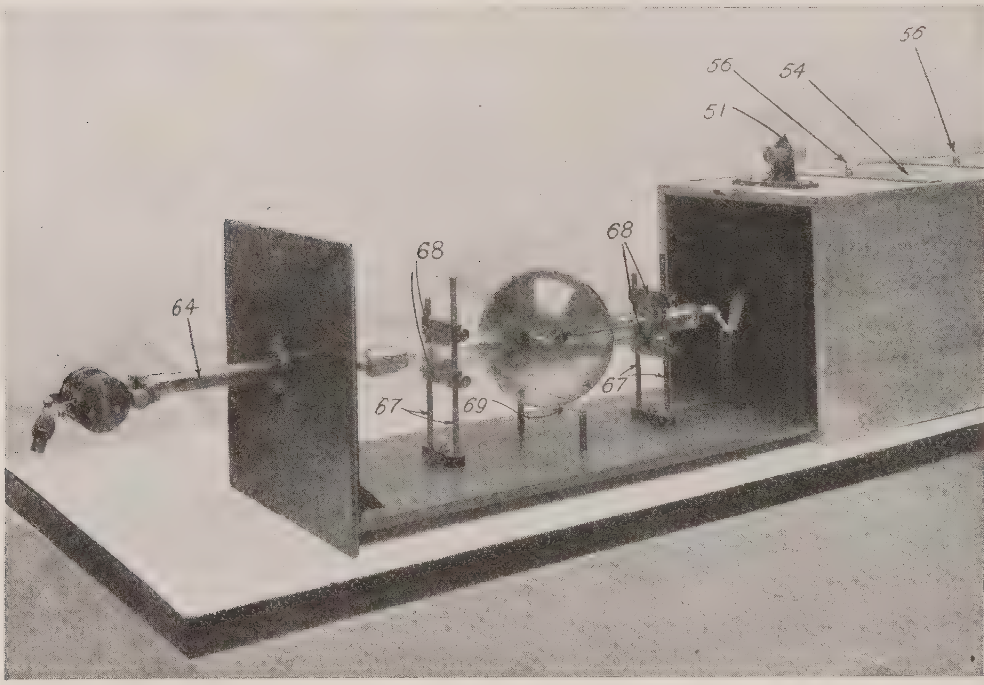


FIG. 66. Mounting of standard type tube in army x-ray table.

Shutter.—(Fig. 65) The shutter has double slides;

one pair controlled by the outer knob (74) gives a diamond-shaped opening; that controlled by the inner knob (75) gives a slit parallel to the length of the table. The shutter is attached to the box by the pins (56) and clamps (71), as shown, and these must be closed before using.

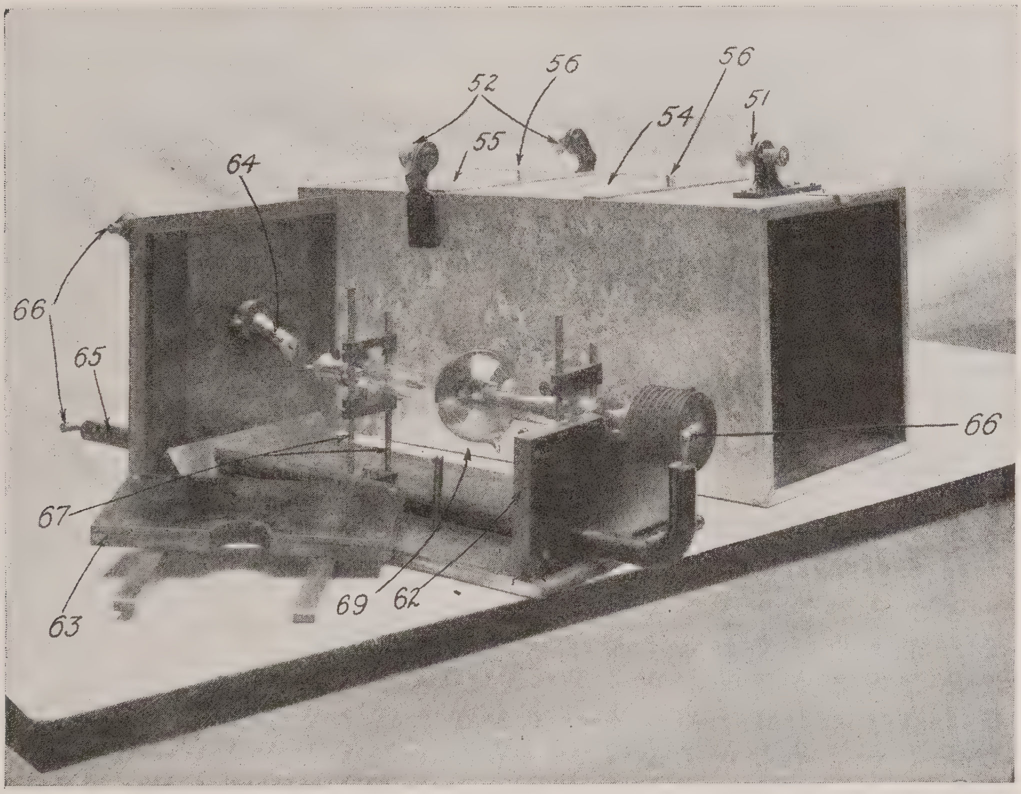


FIG. 67. Tube box and mount for radiator type tube, standard army x-ray table.

Top.—(Fig. 64) The rectangular frame (30) is narrower than the supporting ends of the table, permitting a slight lateral shift of the patient without disturbing him on the stretcher. A raised ridge projects on one side to engage a groove in the stretcher type of top. This allows a certain amount of longitudinal shift. A little paraffin as a lubricant on the ridge will serve to make the top move readily, even with a heavy patient.

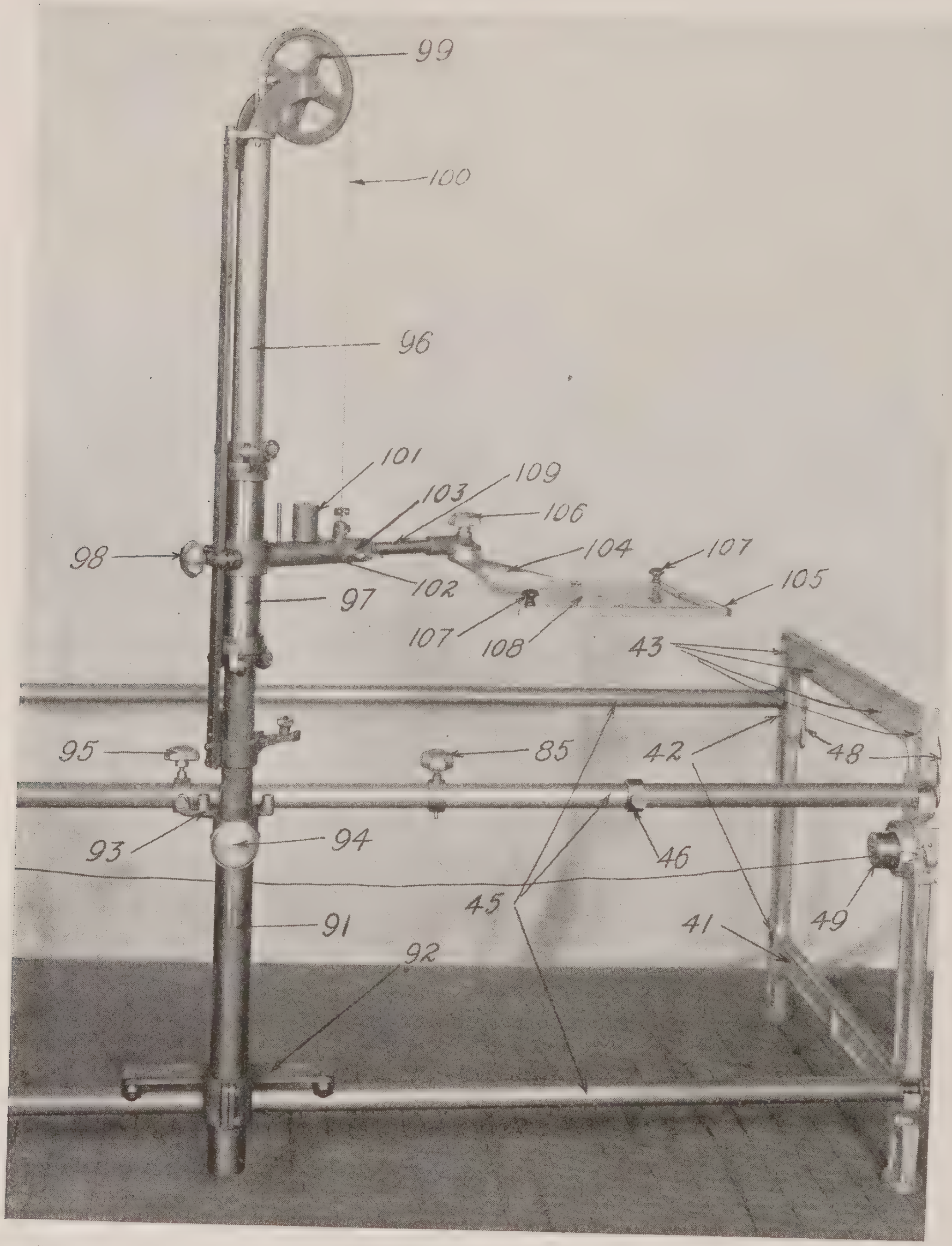


FIG. 68. Screen-carrying mechanism, complete standard army x-ray table.

Switch.—(Fig. 64) When using the "Delco" engine to operate the portable outfit the switch may open and close *two* circuits; in this case the *usual foot switch cannot be used.* A special pull switch (49) operated by a string running along the rail is supplied.

Screen Support.—(Fig. 68) The screen support was designed to enable the screen to be carried to any working position parallel to the table top without having any portion obstructing the work of the operator. For localization work it may be locked in any desired position.

It has the following features:

1. It runs freely on the two side rails.
2. It is counterbalanced so as to run up and down with ease.
3. It may be rotated about two vertical axes, enabling the pierced center of the screen to be brought easily into position.
4. It may be locked against each motion separately.
5. It may be locked as to up and down motion and yet rotate.
6. The screen may be inclined if need arises. The carrier is mounted in a tube (91) with bearings running on the lower rail, and three rollers (93) on a vertical axis hold it in line on the upper rail. (96) is a heavy tube fitting into (91) and turns on a cone bearing at the base. (109) is an adjustable rod to which is attached the screen clamp (106). (98) is the clamp for vertical motion; (95) for longitudinal run; (94) for rotation in the tube; (106) for rotation about the corner of the screen.

Vertical Insulators.—(Fig. 62) The special insulating masts may be used as follows:

1. In base hospital work with an overhead wiring system they serve to connect to the tube box. They are

then placed, one at *each end* on the *operator's side* of the table.

2. To connect the portable instrument box for work with tube above the table. They are then placed both at one end of the table. Two extra reels and a tube holder are needed for this arrangement.

Setting Up Table (Portable)—

1. Unpack all of outfit and check list to ensure that no parts are mislaid.
2. Decide on position for table and instrument box, and which shall be the operating side of table.
3. Lay two rods (45) down on side to be used by the x-ray operator; one of these must have locking and stop rings.
4. Place end frames (41) in position and drop rods into notches. Use all upper notches unless army litter is to be used.
5. Place screen roller carriage (91) in position and tighten end screws on all rods. Run (91) to left of operator's position.
6. Hook cradle under rollers on tube box with the two roller ends of cradle on the operator's side of the table. *Lock cross brake* (51) and set cradle on rails, then release brake (51). Attach working cross lock and be sure it is in proper position. See Fig. 65.
7. Attach diaphragm (70) to box and lock in position.
8. Set (96) into (91), then attach screen and clamp with screw (103).
9. Unlock (98) and put on enough small weights to counterbalance the screen.
10. Attach pull switch to the end of table toward instrument box.
11. Pull out drawer from tube box and place on a good support.

12. Remove cover of inner box of tube shipping case by unhooking the hasps at each end, and raise the corner by grasping each hasp.
13. Place the tube in position shown in Fig. 67. Make the cathode connection by turning the tube in the holder before tightening. Then, approximately center and tighten holder. Connect to the radiator by means of a short piece of wire. Do not use screw as a binding post.
14. Place rectangular frame (30) with ridge away from operator.

NOTE.—Be sure to retain the box intact in which the tube is shipped, and in case of reshipment proceed as follows:

To pack the tube, place it in the inner box so that the radiator is ¼ inch from the end of the box.

Place cover of inner box in position.

Press cover down carefully and close spring hasps, being absolutely sure that the hasp is hooked.

After closing cover of outer box, fasten down by means of the hasp provided for that purpose.

Cautions—

1. Do not bend, bruise or jamb parts.
2. Do not remove screen without first locking (98), as counter weight may cause damage.
3. Do not turn screws so tight that threads are stripped.
4. Do not fail to set cross run brake (51) before lifting tube box off or on.
5. If the supporting side rails are slightly bent the tube carriage will run hard or bind. Place box in the middle of the run and, loosening the end nuts, (48) rotate upper rods about their own axes until the single back roller is free on both sides, i. e., does not rub on its support.

6. Always remove screen from its holder before removing screen carriage.
7. Note the cone bearing on the lower end of the carrier post. Do not stand the carrier on this, as it may easily be roughened.
8. If the screen carrier does not run freely or is too loose at the top, the eccentric mounting on the inside of the roller bearing should be loosened and adjusted so that there is very little play between these rollers and the rail. If tightened in this position the carrier will run freely.

Also, note that the ring (95) has a hole 90° from the handle into which a small thumb nut projects, making the attachment with the movable carrier; while (85) has a projection intended to engage a slot on the under side of the cross piece of the cradle, to serve as a lock for longitudinal run of tube box.

Some Operating Points.—After the table is set up and made reasonably level and all adjustments have been made, it is strongly advised that the operator practice manipulation until he can instinctively and certainly grasp the locking devices whenever necessary for his work.

There are, then, six knobs to be operated, three controlling the screen carrier and three the tube box and diaphragm.

Number 106 will usually be set according to the operator's idea of using the screen and need not generally be unlocked.

It is expected that the operator will stand between the screen carrier and the diaphragm control, using the right hand to control the screen box and its locks. It may be suggested that if the operator will acquire the habit of grasping the rod (109) in order to control the screen position, the left hand need never be in the radiation, and

the right hand can remain free to control shutters and rail lock, Fig. 69. A little time spent in adjusting one's

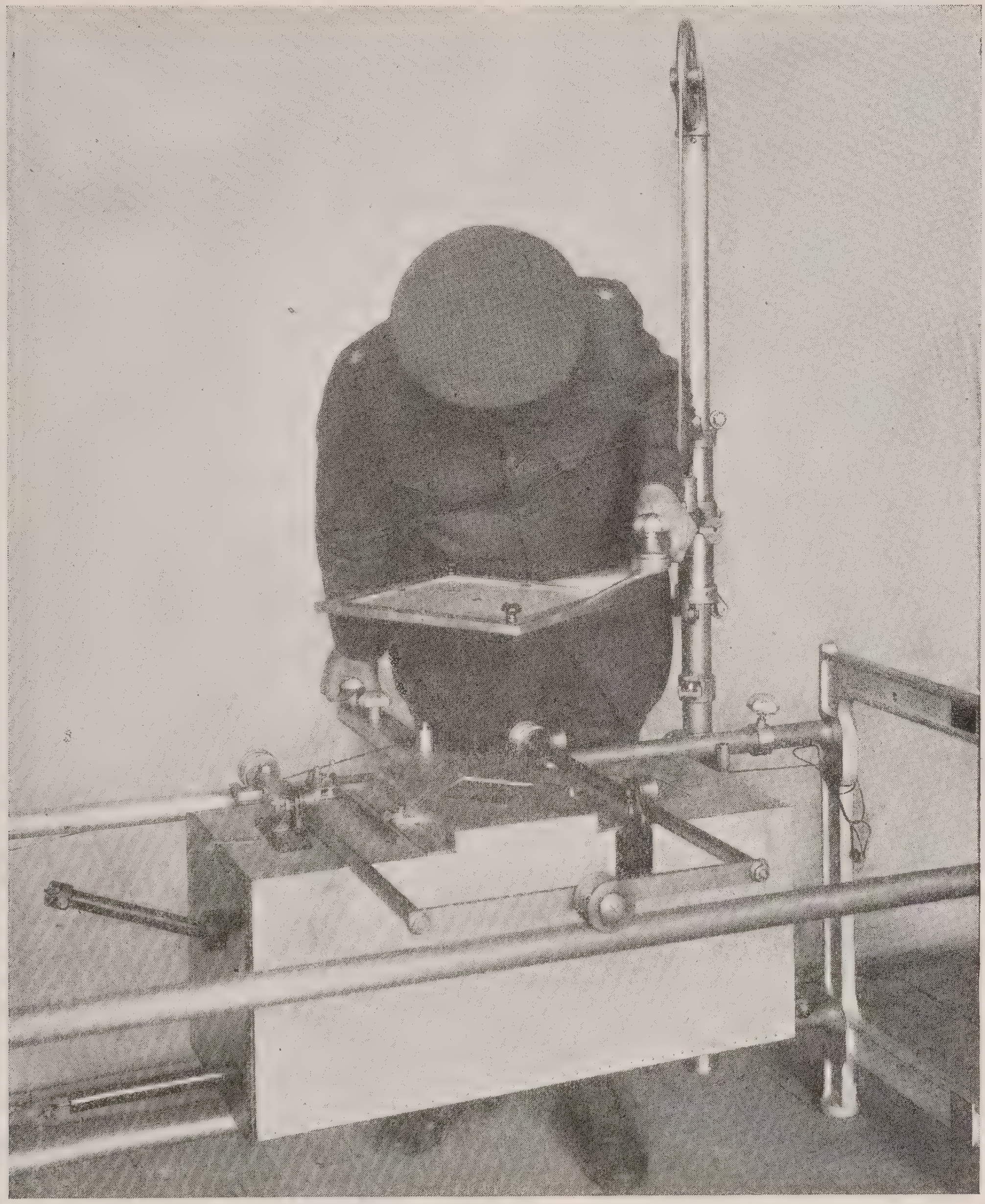


Fig. 69. Method of handling screen and shutter on all standard army x-ray tables. Litter top removed.

motions and ideas to those that prevailed when the apparatus was designed will greatly expedite its accurate use.

List of Numbers Referring to Illustrations of Standard Tables

Numbers refer to the illustrations and *not* to manufacturers' stock or replacement numbers.

PART.	NO.
Top	
Rectangular frame	30
Bakelite stretcher	31
Frame	
End frames	41
End frame slots	42
Holes for mast support	43
Rods (side rails)	45
Ring stop	46
Screw handles on rods	48
Switch	49
Tube Box	
Roller with cross run lock	51
Rollers without lock	52
Aluminum window	54
Ventilation opening	55
Register pins for shutter	56
Lock, cross run	57
Partition (lower half)	62
Partition (upper half)	63
Insulator (cathode)	64
Insulator (anode)	65
Binding Posts	66
Tube support posts	67
Tube clamp	68
Tube centering wire	69
Shutter	
Shutter complete	70
Shutter clamps	71
Screen carrier connecting post	72
Diaphragm opening	73
Diamond-opening control	74
Slit-opening control	75

PART.	NO.
Tube Box Cradle	
Stop position for 10 cm. shift	80
Rollers	81
Stop for variable shift	82
Stop for 15 cm. shift	83
Stop	84
Lock to rail	85
Screen Carrier	
Socket bearing	91
Lower rail carriage frame	92
Upper rail bearing rolls	93
Clamp against rotation	94
Clamp against longitudinal run	95
Main post	96
Sliding sleeve	97
Clamp (vertical position)	98
Pulley	99
Wire cord	100
Balance weights	101
Socket for horizontal arm	102
Clamps (screw)	103
Screen holder frame	104
Screen holder latch	105
Screen clamp	106
Knobs to lift screen	107
Screen	108
Rod to screen frame	109
Additional High Tension Insulators	
Vertical masts	21
Frame for supporting masts	22
Short insulator for keeping high tension wires away from frame	23

Fluoroscopic Room Illumination.—It is strongly urged that the lighting of fluoroscopic rooms be properly arranged. One should have a dim light for use in placing patients, etc., and no light when fluoroscoping. The portable outfit provides for operating the needed light from the Delco generator. When the operating switch is closed the lights go out, and on opening this switch they are automatically lighted. It is advised that a ruby lamp be used intended for operation on a circuit above 110 volts. The connection used with the portable unit is shown in Fig. 76 and a similar connection can be made for other outfits.

To Find Target-Screen Distance.—On the standard army x-ray tables the following method will serve to measure the distance from target to screen:

The upright support U fits in the tube Q, Fig. 70 and the screen carrier is fastened to the sliding sleeve R. The distance from the top of the tubing Q to the under side of R is related to the target-screen distance F_0S as shown, $F_0S = n + d + l$ where n and l are fixed lengths. Hence if *one* target-screen distance is found, $n + l$ can at once be determined.

Put the cross wire marker on the table in the vertical ray. Shift the tube by use of the table stops an exact distance, say 10 or 15 cm., and adjust the screen up or down until the image shift and tube shift are equal. Then the target-screen distance is twice the distance between screen and cross wire marker.

Measure the distance BX and subtract this from the length so found, and the difference is $l + n$. Record this on a shipping tag and attach to the table. Thereafter, if the target-screen distance is required, measure BX and add $l + n$ as recorded.

To check your measurement lay a strip of metal about four inches long on the table. Raise the screen until the

shadow becomes twice the length of the strip. Measure screen-object distance and double the result for *FS*.

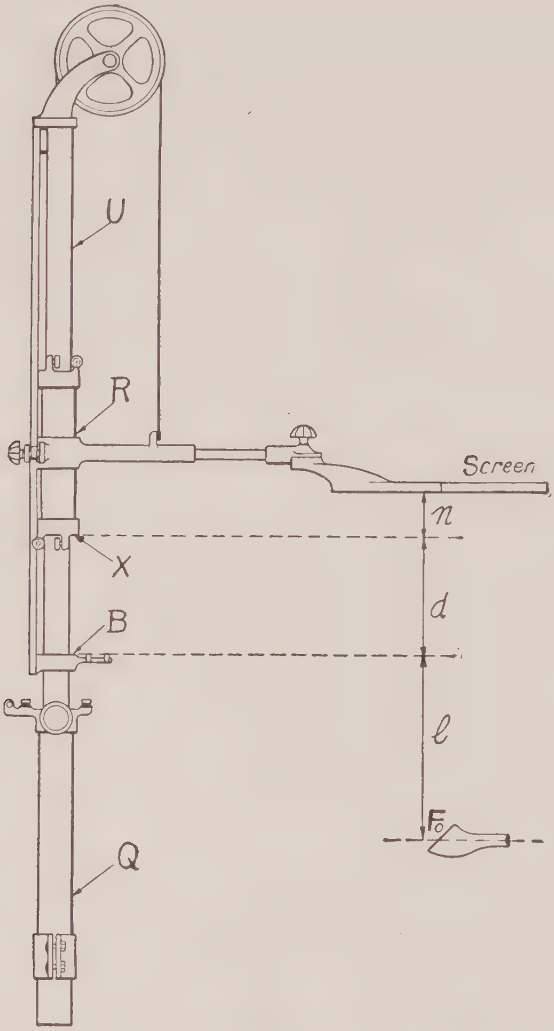


FIG. 70. Measurement of target-screen distance, standard screen carrier.

Examples—

1. Using a 10 cm. tube shift and setting the sliders of method A 10 cm. apart, a piece of lead was placed on the table and its edge so placed that its shadow coincided with one of the metal edges of the marker; shifting the tube 10 cm., the screen was raised until the shadow of the lead

coincided with the other marker. The object-screen distance was then 38.7 cm. The target-screen distance was then $38.7 \times 2 = 77.4$.

2. With length of shadow double that of the object, the actual distance between screen and the object was 39 cm. Double this, or 78 cm., equals the distance between the plane of the screen and the plane of the focal spot of the target.

78 cm.	=	total distance screen to target
45 cm.	=	variable distance
33 cm.	=	the distance that the sliding or adjustable piece on the upright arm of the wall meter is to be raised and set above the brass lug on the lower right.

Centering Tube in the Box Beneath the Table.—It is desirable that the focal spot of the target should be vertically below the center of the diaphragm in the various methods of localization. In order to determine whether this is the case, proceed as follows:

1. Close up the diamond-shaped opening of the shutter to about ½ inch.

2. Lock the tube box in position and bring the opening of the screen so that the illumination shows symmetrically thereon.

3. Suspend a small metal ball, *B*, by a string passing through the center of the opening, and observe when this ball comes to rest whether its shadow falls symmetrically upon the projection of the diaphragm. If not, or if on narrowing the diaphragm still further, the narrow beam of rays passes by the ball so that it does not cast a shadow on the small illuminated area of the screen, it is evident

that the tube is not properly centered, and the position of the shadow also gives an indication of the direction of tube movement require. Fig. 71.

An approximate idea of whether the tube is properly centered or not may be gained by bringing the perforation in the center of the screen to the center of the projection of the small diagonal opening of the shutter. When the

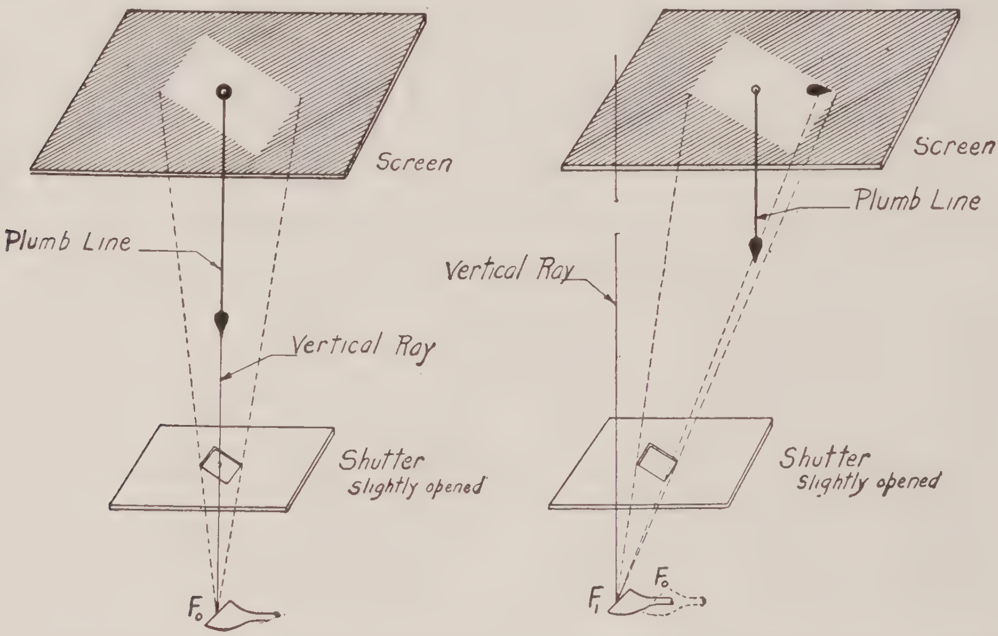


Fig. 71. (a) Correct position of shadow of plumb bob. Tube properly centered.

(b) Projection of plumb bob on fluorescent screen, incorrect position.

screen is down close to the table with the carrier locked against longitudinal motion and against rotation, raise the screen by the vertical movement of the carrier and see whether it retains its symmetrical position. An idea of the amount by which the tube needs to be shifted may be obtained in this way.

It is also suggested that, if the tube needs to be moved in the direction in which the holder slides out of the box, one can slide the holder itself out and test for correctness,

measure the distance, and finally shift the tube the same amount.

The U. S. Army Portable X-Ray Unit.—By the coöperation of various manufacturers a semi-portable outfit has been developed which may be used in mobile units. The unit is shown in Fig. 72 and diagrammatically in Fig. 73.

The important features of the outfit are the portable power plant, the self-rectifying Coolidge tube, and the

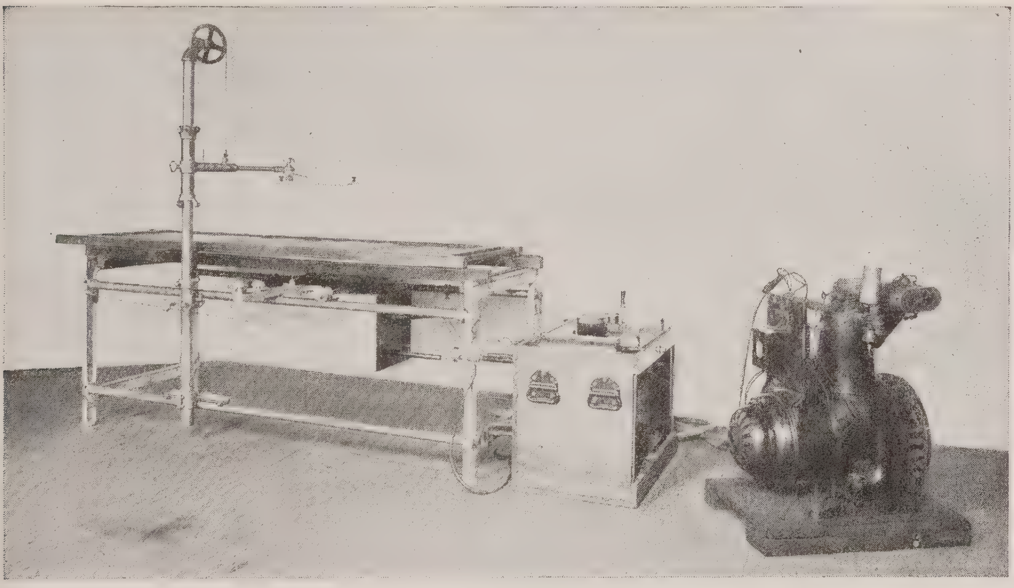


Fig. 72. United States Army portable x-ray unit complete.

special table. Having the complete generating equipment, it is admirably adapted to service in strange territory where the electrical supply is not suitable for standard machines or is likely to fail because of war conditions.

The gasoline engine is direct-connected to a generator which supplies power for the x-ray and filament transformers (a.c.) and a small amount of current (d.c.) for the control circuit. The primary circuit requires no control resistance, regulation for the two working settings being made by shifting the throttle by means of the d.-c.

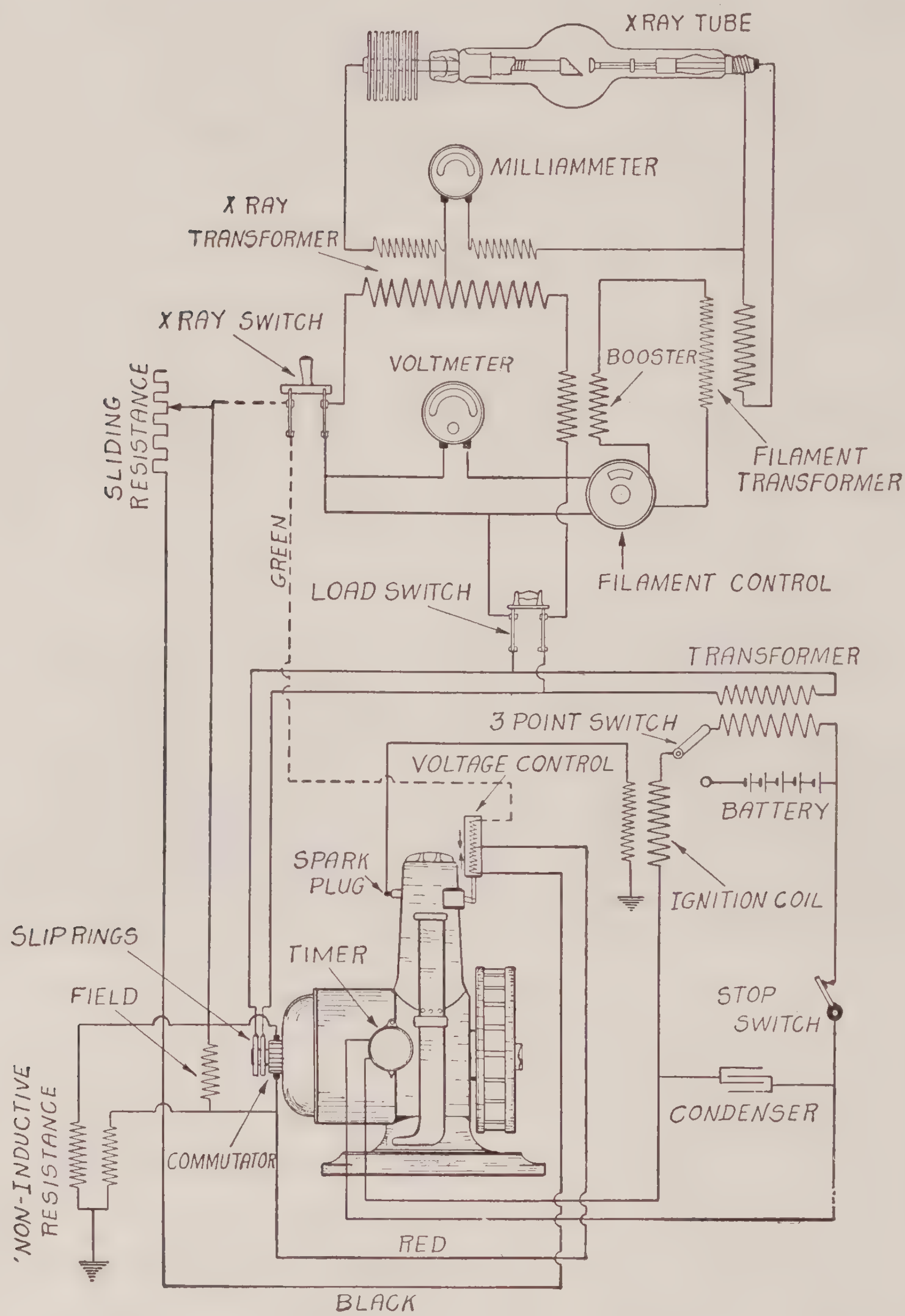


FIG. 73. Wiring diagram for United States Army portable x-ray unit. Dotted lines show connections for those machines having special control. In other cases these wires are omitted.

control circuit, changing the speed and thereby the voltage of the generator. The secondary circuit contains no rectifying device since the tube allows only each alternate half wave to pass. (See page 36 for a description of the tube.)

Fluoroscopic work is done at 5 ma. and all radiographic work at 10 ma. The maximum operating gap is about 5 inches, but may be reduced if desired by control of the machine speed.

Owing to the drop in line voltage upon closing the operating switch, it is necessary to secure a uniform filament current by inserting a "booster" in the primary circuits of the two transformers. This is merely a small transformer, which by carrying the main transformer primary current adds enough voltage to the filament transformer primary to compensate for the drop of voltage in the line.

Engine.*—The engine must be firmly fastened to a solid base by means of lag bolts or by some other convenient method. All fuel must be strained when filling tank, as impurities of any kind are certain to clog fuel pipes.

Use a good grade of medium oil and always make sure that the crank case is well filled before starting engine.

To start the engine, turn the fly-wheel rapidly by means of the crank, immediately remove crank and then press starting button and cut off air by means of lever on mixing valve body. When the engine has run for a few seconds, advance air adjustment lever to the point where the engine runs regularly and with the leanest possible mixture. A little practice will enable the operator to do this very quickly. This adjustment will vary with climatic conditions and the kind and grade of fuel used. It will be found to be slightly different when the engine has warmed up from what it was when the engine was started.

* See also "Delco" circular on model 9011, furnished by the manufacturer.

If the engine does not start, a few simple tests may determine the cause. Go carefully over all wiring and be sure that all electrical connections are tight and clean. Test to make sure that starting battery is not exhausted.

Examine the spark plug carefully and if the porcelain is broken or cracked, replace plug with a new one if possible. Hold the spark plug connecter about 1/8 inch away from spark plug terminal and turn fly-wheel over several times by means of the crank and see if a good spark is obtained in this manner. If not, the plug may be greasy or dirty; remove and clean thoroughly with gasoline and adjust the distance between the points to about 1/32 of an inch, or until a dime can be just passed between them.

Next, look at timer contacts to see that they are properly adjusted and are making good contact every time they close. If necessary, clean these contacts with a piece of fine sand paper. To adjust the distance between the points turn the engine over until the points open to their full extent. In this position a dime should just slip between the points. If necessary, adjust them by turning the contact screw in or out until the proper distance is obtained.

Next, examine commutator and brushes. The commutator may be dirty or greasy. It should never be allowed to remain in this condition, if the generator is to operate at maximum efficiency. Hold a piece of clean cloth soaked in a little kerosene against the commutator while the engine is running. Never use oil other than kerosene on commutator and always wipe dry with a piece of clean cloth afterwards. Examine brushes to see that they are in good condition and are making good contact.

To test your fuel line, fill the priming cup from a small oil can with gasoline, and crank. If the engine will run when using gasoline from the can, and will not run other-

wise, it indicates that fuel connections are loose or that the fuel hole in mixing valve body is clogged. Be sure there is no water in the gasoline tank. The fuel hole in mixing valve body or line may be cleaned out by blowing through it or by means of a fine wire. These few tests will usually locate the trouble. Now look at the cable leads which are all stamped with a corresponding number on the engine switch board. Be sure that they are properly connected to both engine and transformer unit. The amount of gasoline on *continuous* fluoroscopic work will be about 1 gallon per hour. On intermittent work, as is usually the actual case, a gallon will last about 3½ hours.

NOTE.—It may be noted that the wiring diagram as indicated for the portable unit has three wires to the voltage control, and that the x-ray switch has to open and close a circuit, on the left, through this coil and, on the right, through the x-ray transformer. This arrangement was made in order to speed up the engine promptly when put under load, but it has been found unnecessary. In some of the earlier machines, and perhaps in the later ones, this connection may be absent. When this is the case the wiring will be somewhat simpler, since the number of connections will be reduced and a slight change of design of the box may be possible.

The Transformer Unit.—The x-ray transformer unit contains the apparatus needed to transform and control the currents necessary for energizing the radiator type Coolidge tube used with these outfits. It consists of the following parts: (Figs. 74 and 75.)

The x-ray transformer (1) transforms the low tension alternating current from the gasoline engine generator unit into suitable high tension current.

The filament transformer (2) supplies the low tension current for heating the filament of the x-ray tube.

The booster transformer (3) keeps the filament of the x-ray tube constant.

The filament control (4) varies the amount of current

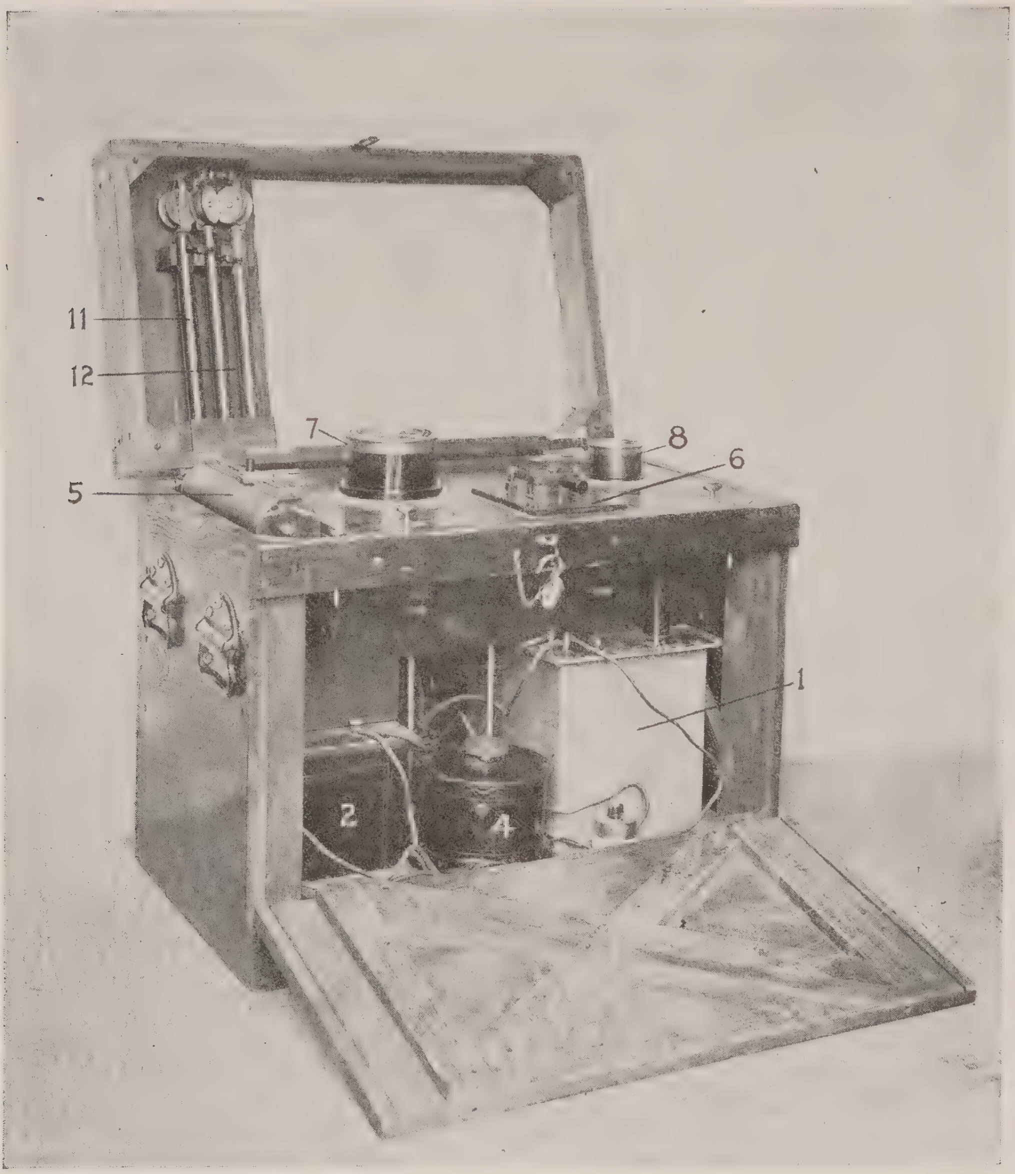


FIG. 74. Instrument box for portable unit, front view.

passing through the x-ray tube. A small knob will be found projecting from the side of this regulator—this is to open and close the circuit through the primary of the

filament transformer. When pushed in it is closed, as it should ordinarily remain.

The engine rheostat (5) serves as a means for controlling the speed of the gasoline engine. Moving the contact toward the front of the box increases the speed of the engine and thus raises the voltage of the generator.

The x-ray switch (6) opens or closes the circuit to the primary of the x-ray transformer and to the auxiliary throttle control.

The voltmeter (7) measures the voltage of the generator.

The milliammeter (8) measures the amount of current passing through the x-ray tube.

The main terminal board (9), whose five terminals project from rear side of the case, provides a means for connecting the x-ray transformer unit to the gasoline engine generator unit by means of the cable.

The pull switch terminal board (10) is, as the name indicates, for the purpose of attaching a pull switch to the apparatus. The split lugs at the end of the switch cable are to be inserted into the sockets in this terminal board to connect the pull switch in circuit. These connections put the pull switch in parallel with the x-ray switch and permit the closure of the circuit by either independent of the other.

After the engine and x-ray table are set up, place the x-ray transformer unit in position, *close* to the end of the table and so that the high tension outlets are equally spaced between the legs of the table. This is very important and should not be forgotten.

Unlock the box, raise the lid to an angle of about 45° from horizontal, and slide the cover of the box slowly to the left until the two hinge sections have been disengaged one from the other. The cover can now be removed from the box.

Pull out the two door bolts. The door in front can now be let down so that work can be done readily in the interior of the box. This door should be kept open at all times when the unit is in operation to avoid damage by corona, etc.

Push the split terminal lugs at one end of the cable into

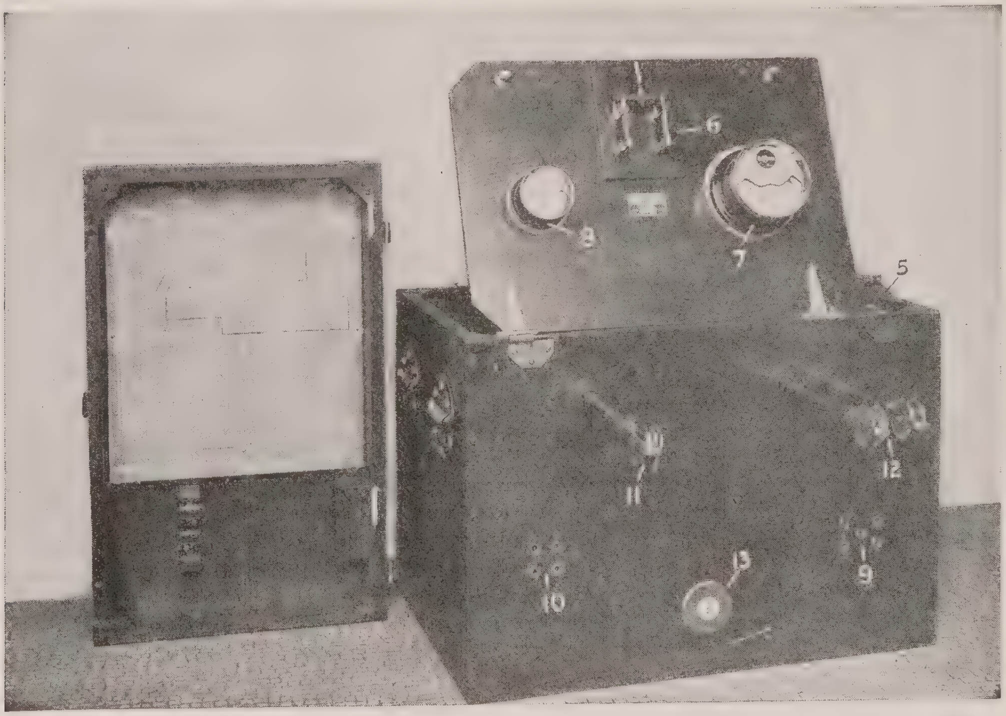


FIG. 75. Instrument box for portable unit showing instruments, high tension terminals, and openings for connections.

the sockets on main terminal board. These lugs are of different sizes so that they will only fit one way in the terminal board, and no mistake should be made. Connect the numbered lugs at the other end of the cable to the correspondingly marked connection posts on the switch board of the engine. Connect pull switch, if one is to be used, by inserting the split lugs on the switch cable in the sockets in the pull switch terminal board.

The high tension terminals (11) and (12) will be found

held in place in the cover by means of a clamp device. These terminals should be removed and screwed into the sockets.

These sockets and terminals are provided with different sized threads at their ends so that the terminals can only fit into their proper socket. The high tension terminal (11), provided with the spring hook terminal, screws into the single socket. The remaining terminals (12) can be screwed one into each of the remaining sockets.

Attach the cord from the positive terminal to the positive terminal of the tube box and the cords from the two negative terminals to the two binding posts on the negative terminal of the tube box.

Open the x-ray switch, the pull switch, and the line switch on the board of the engine; move the sliding contact of the engine-rheostat as close to the hinge side of the box as it will go. Start the engine and close the switch on the switch board of that unit. The filament of the tube should now be incandescent. Slowly move the contact on the engine rheostat toward the front of the box. The voltmeter should indicate higher and higher voltage. Continue until the voltmeter indicates about 160 volts.

For radiographic work, having adjusted the engine speed by means of the engine rheostat until the voltmeter reads 160 volts, set the filament control at 1.9, close the x-ray switch and readjust the engine rheostat and filament control until the milliammeter reads 10 ma., when the voltmeter should read from 110 to 115 volts.

Now open x-ray switch and read the voltage generated at no load, leaving the rheostat set in the 10 ma. position. Hereafter, whenever radiographic work is to be done, simply adjust the engine rheostat until the voltmeter indicates the voltage thus found.

To obtain the operating point for fluoroscopic work, viz.,

5 ma. at from 110 to 115 voltmeter reading, reduce the speed of the engine by means of the engine rheostat until the milliammeter indicates 5 ma. Upon examination of the voltmeter, it will be found to read from 110 to 115 volts. Open the x-ray switch and read the voltage generated at no load, leaving the engine rheostat set at 5 ma. point.

Hereafter, whenever fluoroscopic work is to be done, adjust the engine rheostat until the voltmeter again reads the voltage thus found.

In order to save fuel and wear and tear on the engine, it may be advisable to run the latter on reduced speed, except when making a radiograph, or during a fluoroscopic examination, or when it is desirable to use red room lamps designed for this unit. For this reason an adjustable stop is provided on the engine rheostat. This stop is set to bring the engine to proper speed for the work in hand, so that during the interval between making radiographs or fluoroscopic examinations, the engine speed can be reduced and reset for the next operation by merely running the contact against the adjustable stop.

This x-ray transformer unit should, as far as possible, be kept dry inside and out, and should be kept covered with a tarpaulin when not in use. Care should be taken to prevent sudden jarring and rough handling generally, to minimize the danger of putting meters, etc., out of adjustment.

The filament control must be adjusted carefully to give the proper current and primary voltage, and once adjusted it will stay fixed. Make sure the filament is lighted before throwing on power: this may easily be forgotten with an enclosed tube.

Should a spark pass in the secondary circuit when the operating switch is closed, it may be due to a temporary

surge. Unless an "arc" results, do not open the operating switch. Keep secondary wires well apart and well away from other objects to prevent corona and leakage. It is a good plan to connect the frame of the table to any convenient "ground."

Red Light for Fluoroscopic Room.—The generator may readily serve to give the reduced red light needed in fluoroscopic work. Fig. 76 shows how this is done; and either a

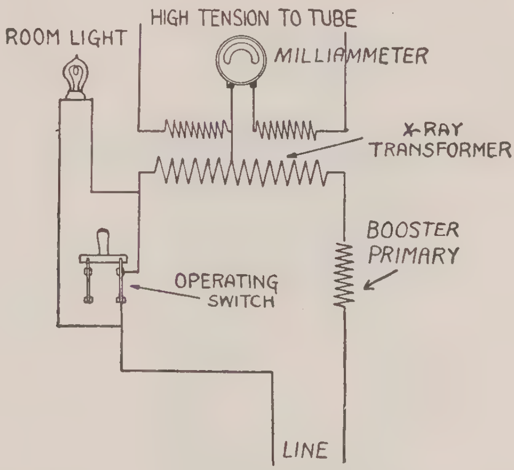


FIG. 76. Connections for red lamp over the fluoroscopic table, when used with portable unit.

high voltage ruby lamp or two 16 candle power, 110 volt ruby lamps in series are required. Do not connect in except as shown and do not attempt to load the generator up with additional lights or apparatus. Pulling the string switch alternates x-ray excitation and darkroom illumination. The extension cord and light connect onto the box at 13, Fig. 75.

Limitations.—This instrument will do the work for which it is designed, but must not be abused. Do not use the radiator type Coolidge tube on large installations or interrupterless transformers. It is not furnished for this purpose. It should only be used for radiographs at 10

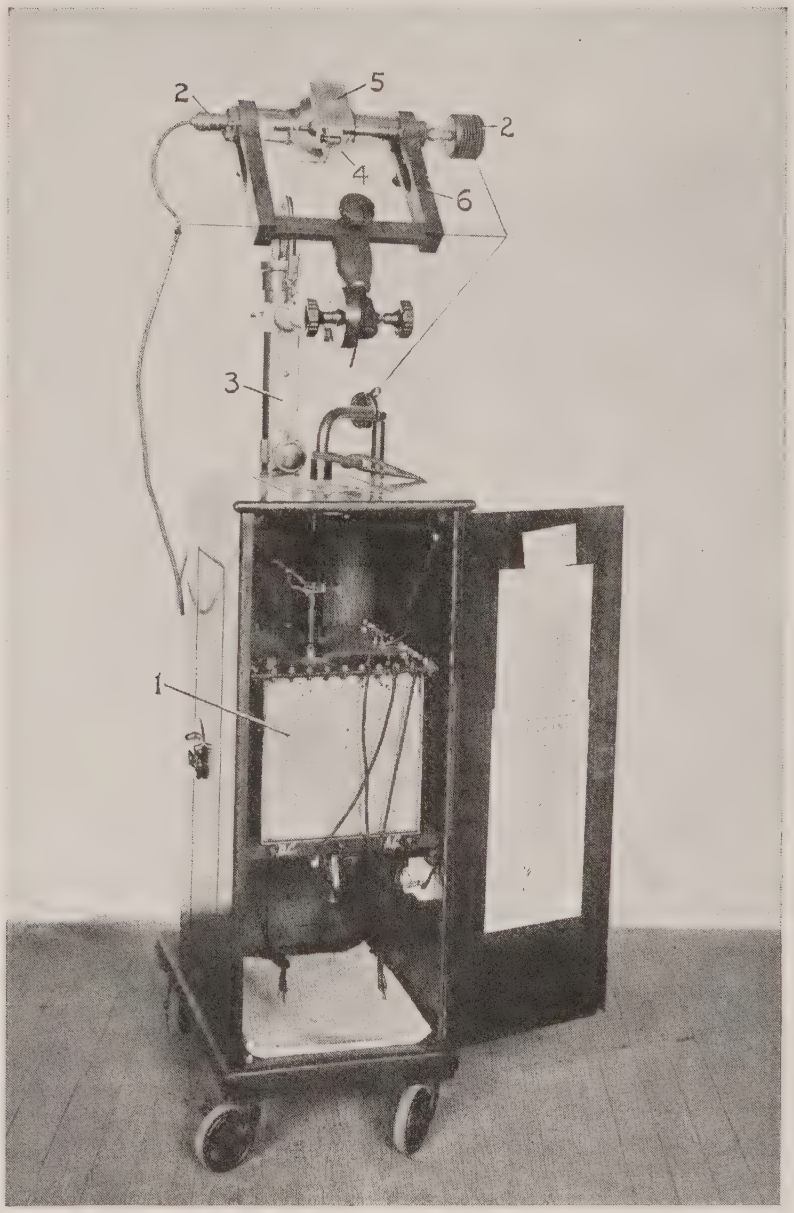


Fig. 77. United States Army bedside unit, complete for alternating current operation; double throw switch to be drawn to the right, loose connections below for rotary converter in using direct current.

ma. for a maximum exposure not exceeding 45 sec. with two minute intervals between. For fluoroscopic work it may be operated continuously, long enough for all practical necessities, at 5 ma. Do not attempt to use this tube at

other than these settings. Never attempt to operate the tube without the radiator.

The U. S. Army Bedside X-Ray Unit.—The unit shown in Fig. 77 was designed to permit x-ray examination in wards to be made with a *minimum* of disturbance of the patient. Many cases of fracture and other bone lesions, as well as various chest conditions, need such examinations. Pressure on the main x-ray outfit is often reduced and time saved by using such a unit.

This unit consists of a combined cabinet and tube stand, a radiator type Coolidge tube, special lead glass shield, and a transformer and control apparatus. The latter are enclosed in the cabinet.

Transformer.—The transformer (1) is designed to operate on alternating current of any ordinary frequency, if properly connected for the supply voltage available. Since the same primary circuit supplies power for both filament lighting and x-ray operation only one switch needs to be opened or closed.

Tube.—The radiator type of tube (2) with a special molded lead glass shield is used exclusively on these units. The tube will operate continuously with 5 ma. at a voltage sufficient for fluoroscopic work.

Tube Stand.—The tube stand (3) is counterbalanced and permits placing the tube in any desired position. It was made with a long horizontal extension to allow work over the top of a bed. The position of the tube during a fluoroscopic examination should be controlled by a properly trained assistant. See Fig. 78.

Limitation of Tube Current.—This outfit was not designed to permit variation by the operator of either current or voltage. The power limit was fixed by the usual fuse capacity of interior wiring for lighting purposes. More power would tend to blow fuses and thus interfere

with other uses of these circuits as well as delay the x-ray work. It gives a good average result when two conditions are met: (1) a tube current of 5 ma.; (2) a proper low tension voltage applied *to the transformer terminals.*

Service Conditions.—The user may find it necessary to operate on any one of the following supply systems.

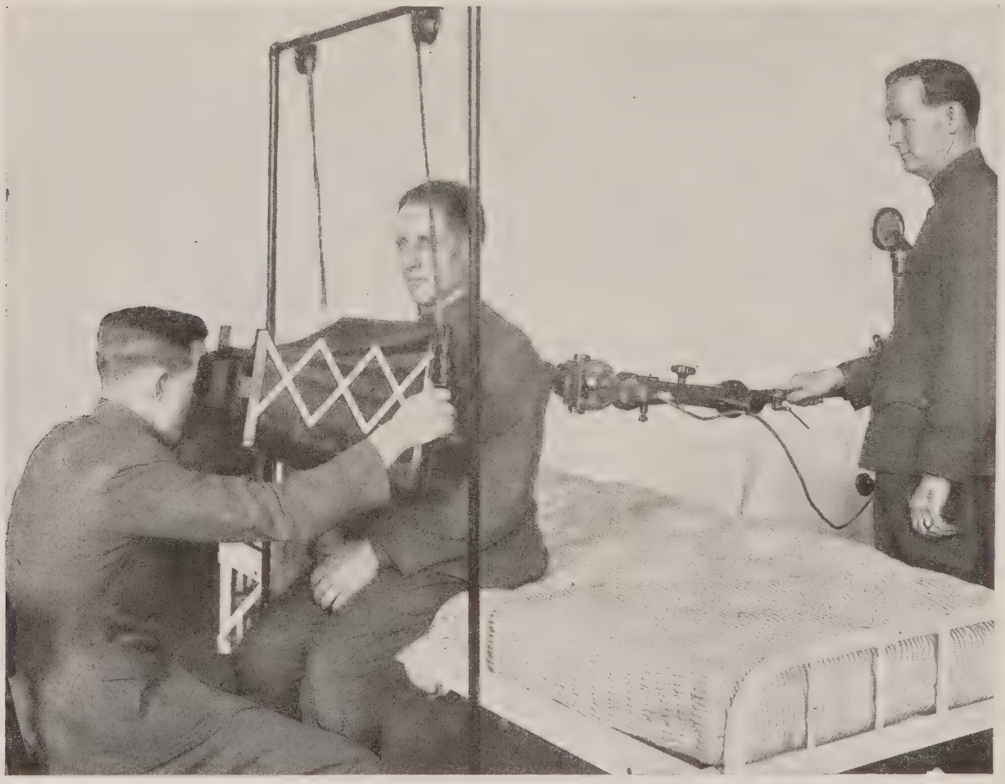


FIG. 78. Positions of parts when using the bedside unit with simple vertical fluoroscope for chest examination at the bedside.

1. 110 volt—alternating current.
2. 220 volt—alternating current.
3. 110 volt—direct current.
4. 220 volt—direct current.

Operation.—To operate this unit the first thing that it is absolutely necessary to know is whether alternating or direct current is supplied and at what voltage. Where any

question exists as to this point, no attempt should be made to operate until all doubts are settled.

This unit will operate satisfactorily on 110 volt alternating current with no accessories. If the supply is 110 volt direct current, a rotary converter must be used, Fig. 79. This is connected by cables which will be found properly connected to the switch in the cabinet. Two leads are to

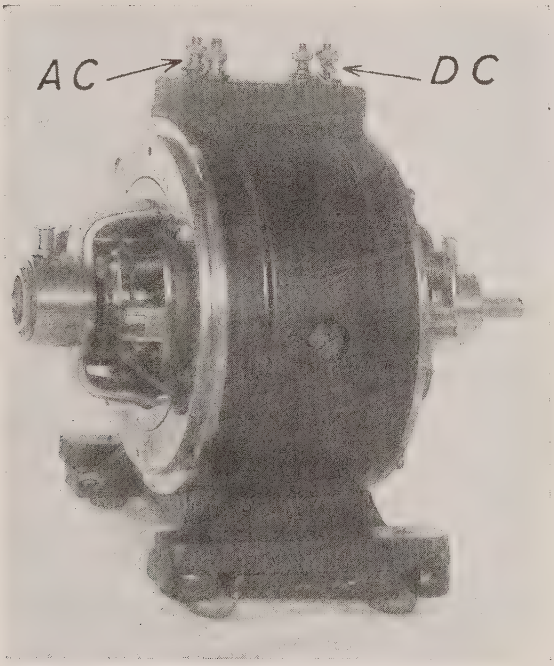


Fig. 79. Rotary converter used for direct current operation. U. S. Army bedside x-ray unit.

be connected to the binding posts on the rotary marked d.c., and the remaining two to the a.-c. terminals of the rotary. No mistake should be made, as these cables are plainly marked. On 220 volt, *direct* current, this unit may still be used, but a 220 volt rotary will be required. The rotary converter for 220 volts is mounted on a wooden base and has a suitable series resistance. This rotary is designed and adjusted to give 110 volts a.c. at the collector rings under load.

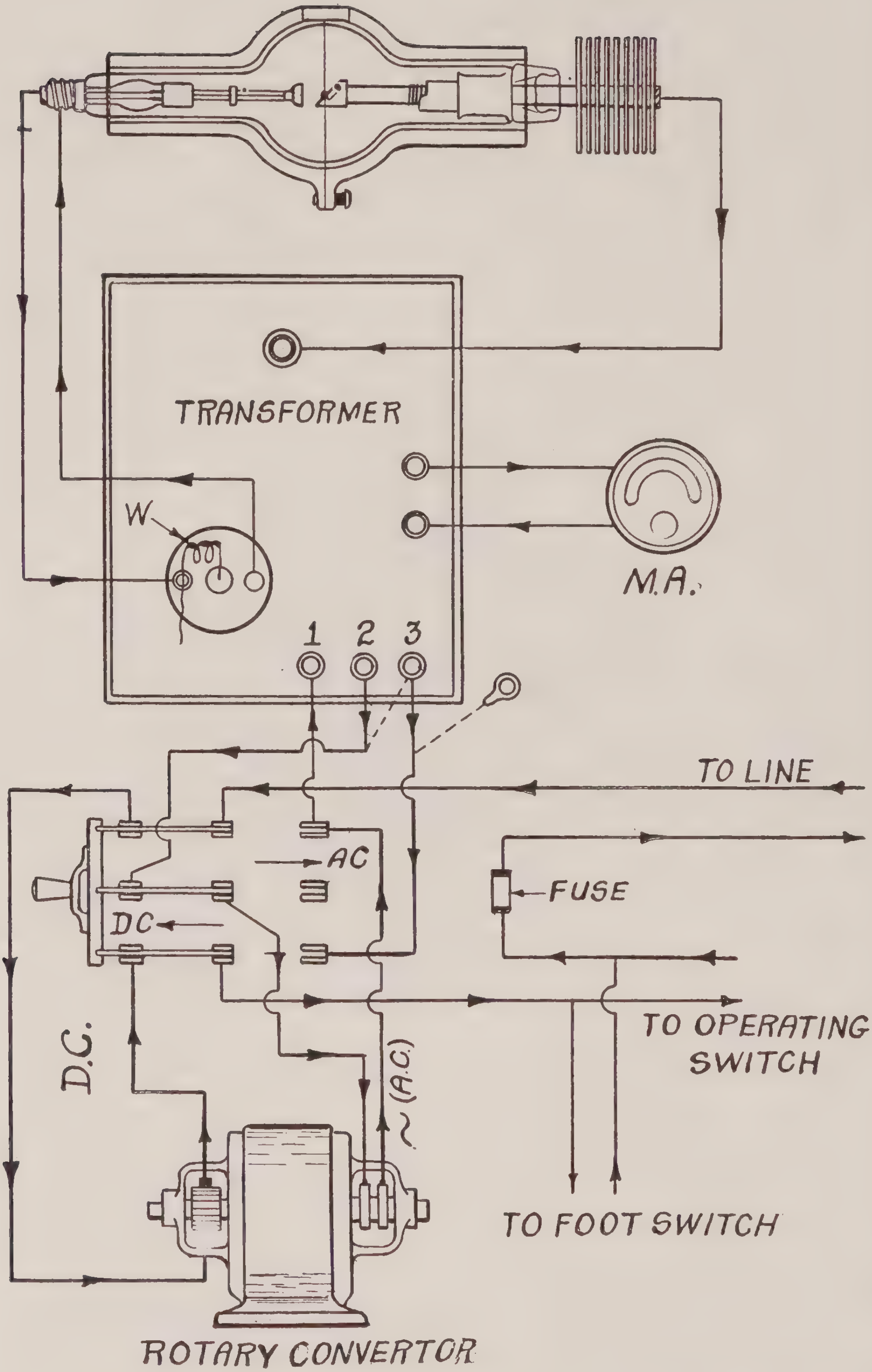


FIG. 80. Wiring diagram for connections, United States Army bedside unit for 110-220 volt, d.c. or 110 volt a.c.

X-Ray Transformer.—The x-ray transformer has three binding posts numbered 1, 2, and 3. One and three are used in *all cases except* for 110 volt direct-current opera-

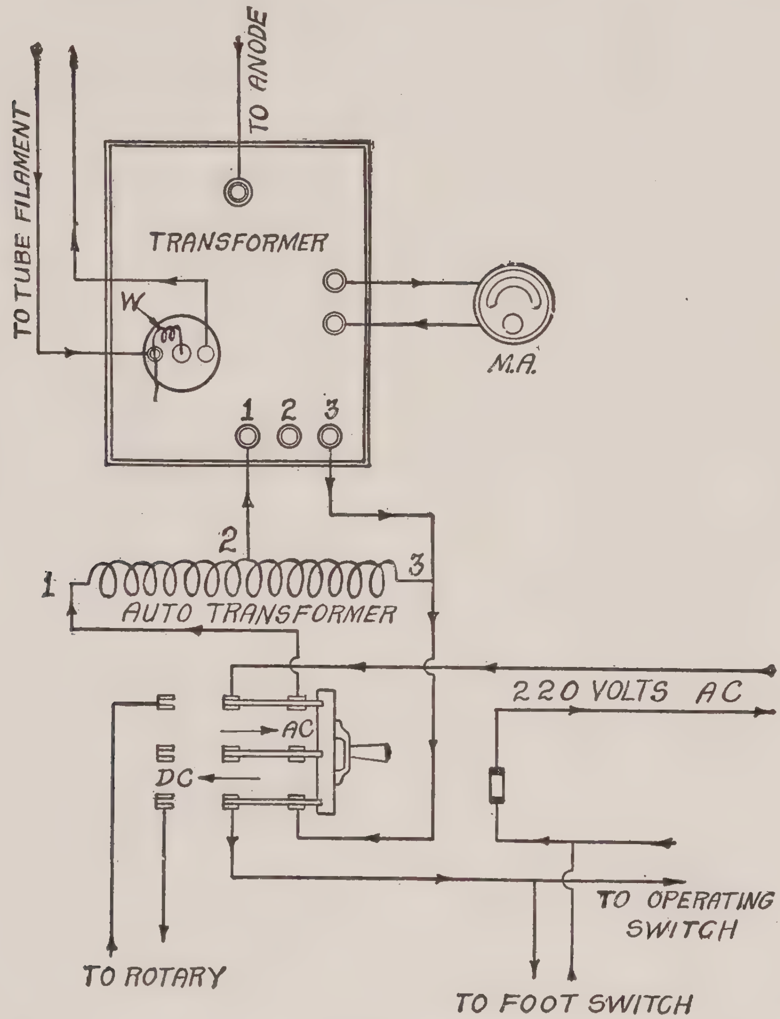


FIG. 81. Wiring diagram for connections, United States Army bedside unit for 220 volts a.-c. circuit.

tion, for which numbers 1 and 2 are used. When the wire is removed from part three it should be taped so as not to make an accidental contact. Fig. 80 shows in full lines the connection for 110 volt d.c., 220 d.c. and 110 a.c. The switch must be closed on d.c. for both direct-current volt-

ages, and on the a.c. side for both voltages of alternating current.

If the current is 220 alternating a special autotransformer is required. The one that is supplied has three wires marked 1, 2, and 3. To connect up for this voltage (Fig. 81) transfer the line wires to terminals 1 and 3 of the autotransformer and connect 1 of the x-ray transformer to 2 of the autotransformer and 3 of the x-ray transformer to 3 of autotransformer.

Tube.—The radiator type Coolidge tube will be used exclusively on these outfits and little or no adjustment can or will be left to the operator. This tube does not require a rectifier of any description and will safely carry 5 ma. for an indefinite time. For radiographic work it is advisable to use intensifying screens.

To Adjust the Tube—

1. Remove radiator after loosening screw at the end.

2. Carefully place the two halves of the lead glass shield (4) over the tube and fasten together by means of the screws. Do not turn screws tight or a broken shield is sure to result.

3. Turn the tube so that the center of the target is in line with the opening in the shield (5).

4. Push the cork wedges, which are supplied, in around the target end of tube first, then in around cathode end so as to hold tube firmly in this position. Replace radiator. If this screw does not turn easily, hold the tube by the radiator and *not* by the glass. Never attempt to operate this tube without the radiator in place.

When placing the tube in the holder be sure that the shield containing the tube is clamped in the holder (6) and *not* the tube ends. To adjust the aluminum filter, which it is necessary to use at all times, loosen the two screws that hold the shield together each side of the opening, place the

aluminum filter in position and retighten screws, always remembering that glass will break if fastened too tight. The diaphragm with the round hole will cover an area 5 inches in diameter at 20 inches target-screen distance, and the square opening an area 14 inches square at the same target-screen distance. A strip of lead foil may be attached by adhesive tape over the crack between the two halves of the lead glass shield.

After everything else is ready connect with your source of current and make sure that you throw the two-way switch to the correct side. Both ends are marked and there can be no excuse for not doing this right. After throwing this switch, watch the milliammeter. If it goes to more than 5 ma., adjust the resistance wire on the top of the terminal inside the cabinet, increasing the amount included between binding posts; if less than 5 ma., reduce the amount so included until the milliammeter reads between 4½ and 5 ma.

This apparatus, operated as directed, will do the work for which it was designed. The operator should not attempt any adjustments other than those described. All others have been attended to by the designers and makers. It is intended that intensifying screens should be used with this unit for all radiographic work, unless immobilization is easily accomplished.

Care in Moving.—The tube holder permits of placing the tube as shown in Fig. 77, so that when moving in a ward there is less danger of collision between the tube and other objects. Always move carefully as the tube is fragile. When the holder is extended the cabinet is less stable, and even more care must be taken. When moving up or down stairs always remove the tube and clamp.

Exposure.—The exposure required with this outfit will depend on conditions as to film or plate, and on whether

an intensifying screen is used and its speed. If one is accustomed to using 40 ma. at about a 5-inch gap, with the same conditions as to distance and plate or film, the time of exposure is to be multiplied by eight. Using an intensifying screen will reduce this exposure an amount depending on the multiplying power of the screen used. A good screen will reduce the exposure time to from 1/10 to 1/15 of that required with no screen, when a plate or a single-coated film is used.

If a double-coated film is supplied, the time without screens is reduced to ½. For double-coated film and single screen, the time is further reduced, under good conditions, to about 1/25 or 1/30 of that for single coating and no screen.

An excellent chest negative of a man of average size has been made with the following settings:

Target-plate distance—28 inches.

Current—5 ma.

Eastman double-coated film.

Edwards screen (single).

Exposure time—1 sec.

A little care and practice will enable one to do a large amount of work at a minimum of disturbance or discomfort to the patient and with quite reasonable exposure times.

Accessory Apparatus.—Hand fluoroscope 5 x 7, the usual type for examination of extremities.

Fluoroscope for chest examination with special support. See Fig. 78. This can be folded and disassembled for moving from place to place.

Reducing goggles are furnished to enable the operator to find his way around a lighted room and then proceed at once to do reasonably good fluoroscopic work. These contain a red and a green celluloid disc; for a fairly dark

room the red alone may serve, for a brightly lighted room both are inserted. Just before bringing the fluoroscope in position, close the eyes, raise the goggles to rest on the forehead, and open the eyes only after the fluoroscope is in position. Reverse these steps when the examination is completed.

Fluoroscopic Unit.—For the most successful and convenient fluoroscopy the operator should have control over both screen brightness and the penetration of the rays. A unit embodying these control features and of correct capacity for operation with the self-rectifying Coolidge tube has been devised and is in limited use in connection with the horizontal and vertical fluoroscope, although not officially adopted and regularly supplied by the government. The transformer is about the same size as that used in the bedside unit but differs in having entirely separate high tension and filament transformers in the same case, rather than two secondary windings energized by the same primary as has the bedside unit. The primary of the high tension transformer and the primary of the Coolidge filament transformer may be separately controlled by turning two knobs on the control cabinet, giving various tube currents and voltages with a much simpler adjustment than heretofore in use.

This unit serves, in those instances where it is installed, to remove the fluoroscopic work from the large standard machine and thereby increase the capacity of the x-ray room without the addition of another high power outfit. It can be run from 110 volts a.c., from 220 volts a.c. by means of a small autotransformer, or from 110 or 220 volts d.c. with a suitable rotary converter. A wiring diagram is supplied with the machine.

STANDARD POSITIONS

It has been the endeavor, in the following series of photographic reproductions of the various parts of the body, to illustrate what seem the simplest and most reliable methods of securing x-ray plates of these various parts, which are of most value in determining both the normal and the pathological structure.

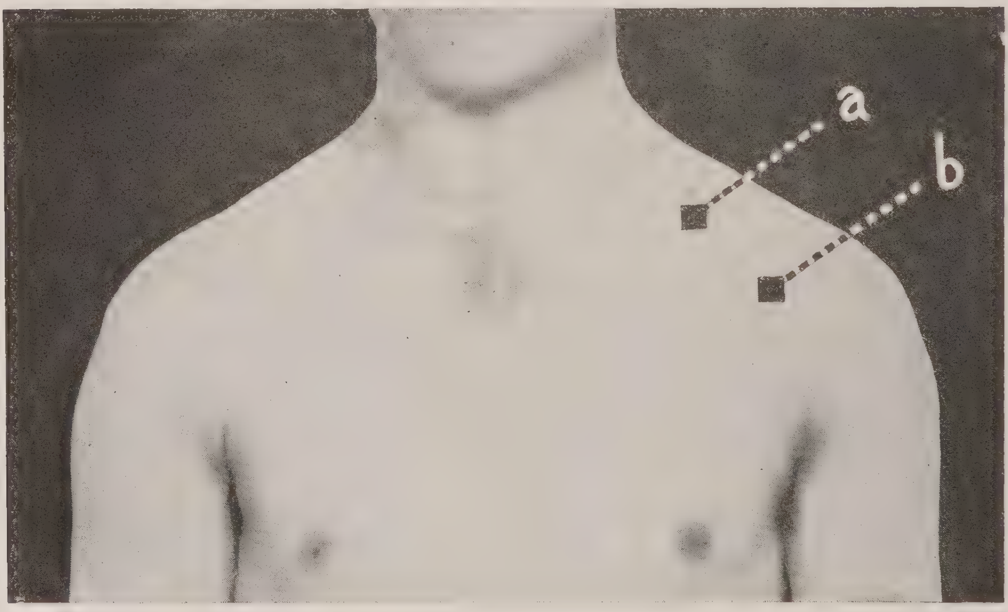


FIG. 82. Position: (a) clavicle (b) shoulder joint.

The necessity for a thorough knowledge of normal x-ray shadows is too apparent to need further discussion here. No amount of study and observation of pathological or abnormal conditions will be of value unless the individual has first acquired a true concept of the normal. In order

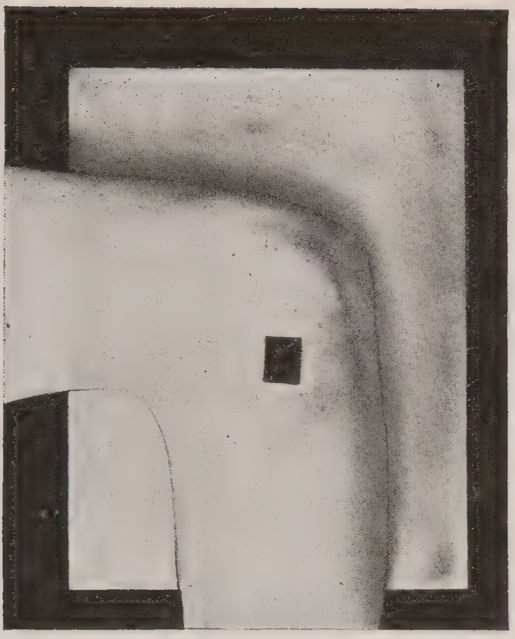


FIG. 83. Elbow, lateral view.

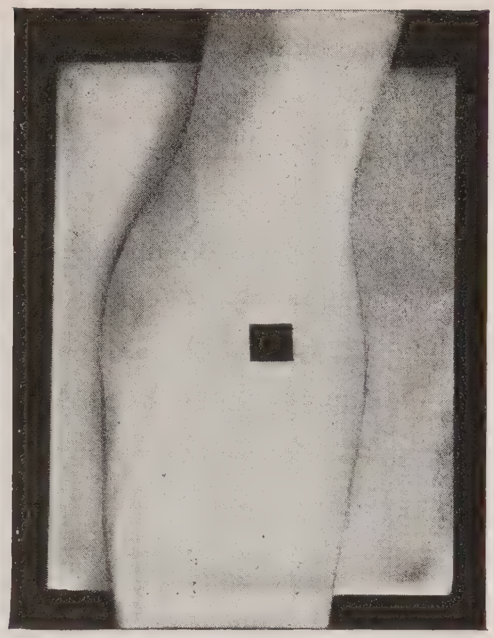


FIG. 84. Elbow, anteroposterior view.

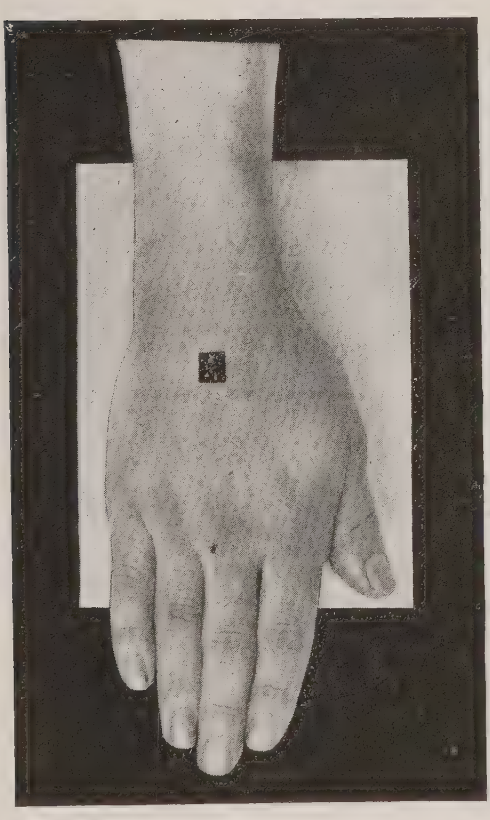


FIG. 85. Wrist, anteroposterior view.

FIG. 86. Wrist, lateral view.

to obtain such a concept some method must be followed which will give the least amount of variation in the apparent size, shape, and relation of the parts examined when attempting to reproduce the same results in the same or different patients. This is essentially the funda-

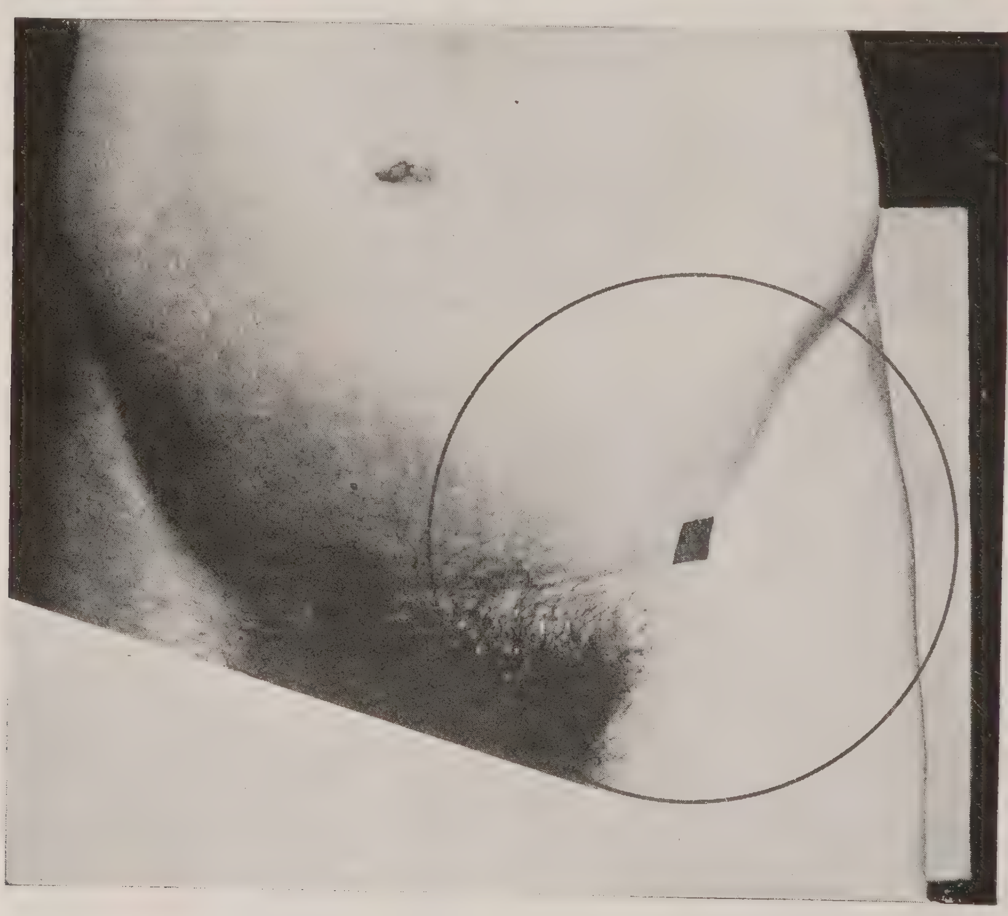


FIG. 87. Hip joint, anteroposterior view.

mental principle of all x-ray interpretation. It has been found by roentgenologists that this can only be accomplished by establishing standard relations between the source of the rays, the sensitive plate and the part to be examined. This is what is meant when speaking of the standard positions for the different parts of the body. It must be constantly borne in mind that even a slight change

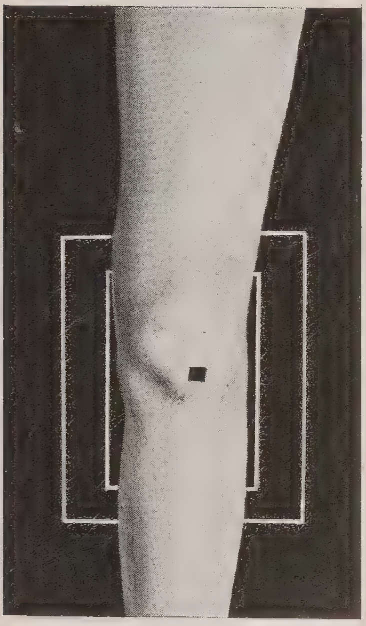


FIG. 88. Knee, antero-posterior view.

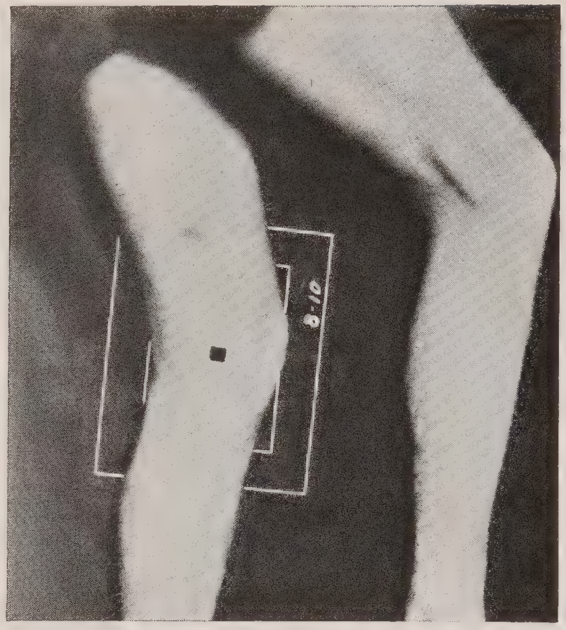


FIG. 89. Knee, lateral view.

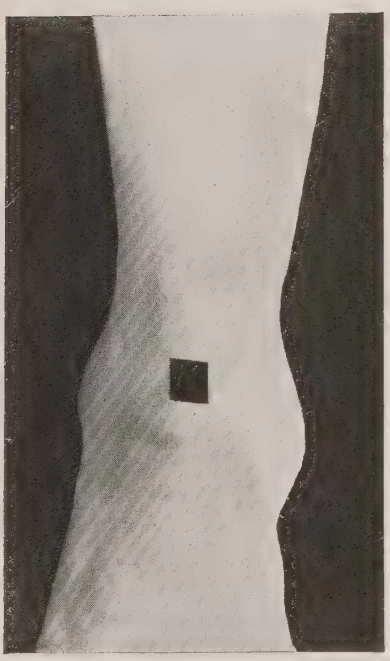


FIG. 90. Ankle, antero-posterior view.

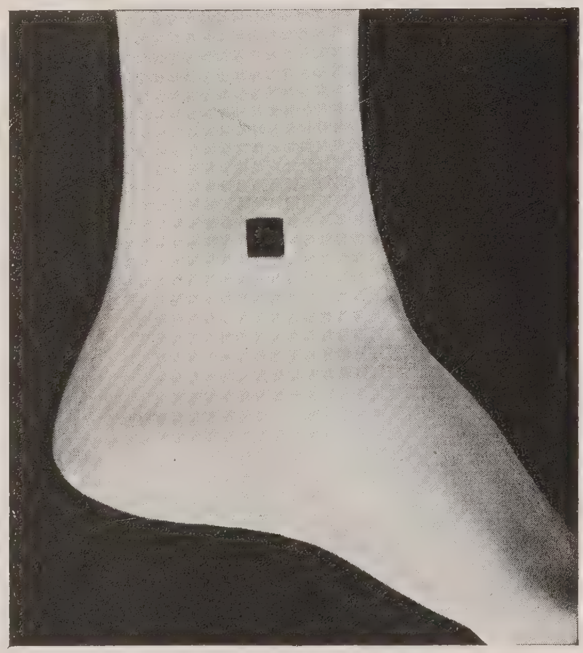


FIG. 91. Ankle, lateral view (marker over internal malleolus).

Fig. 92

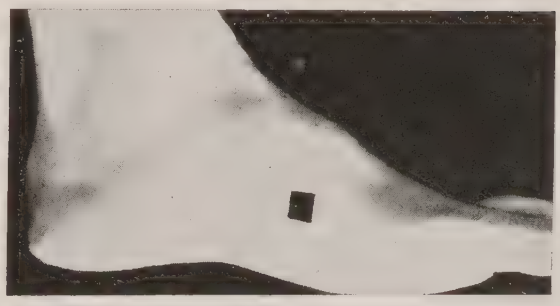


Fig. 93

Fig. 92. Foot, anteroposterior view.

Fig. 93. Foot, lateral view, marker over first metatarsal.

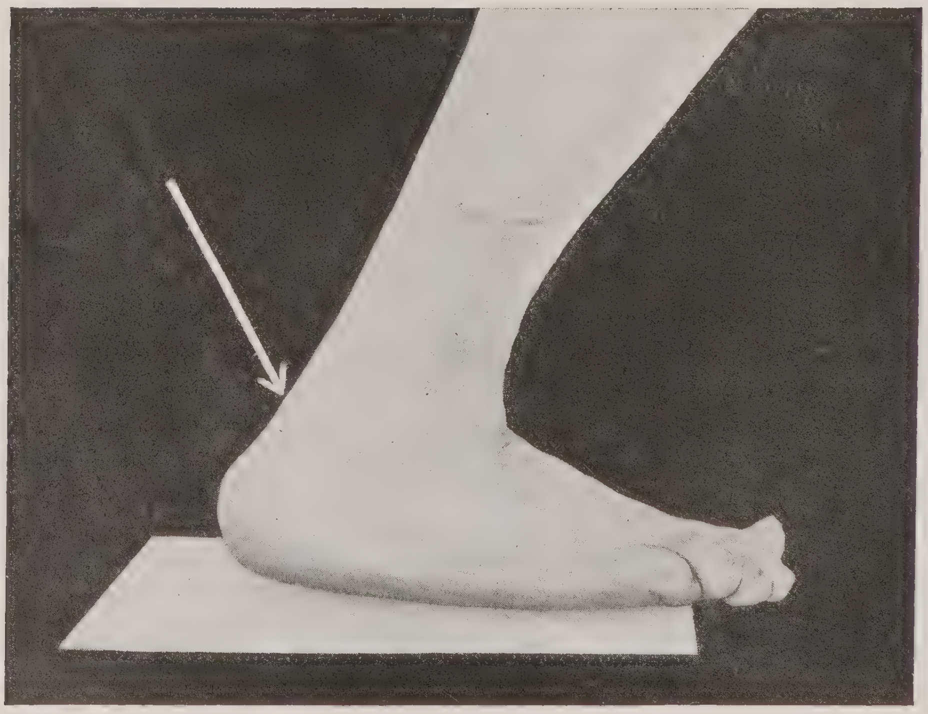


Fig. 94. Position for demonstration of the posterior portion of os calcis; arrow indicates the direction of the rays.

in the relative positions of the target, plate, and part may result in some distortion which might render the plate of doubtful value in any endeavor to determine the abnormal by its comparison with the normal. While experience has shown that the best results are obtained by adhering to these positions, it must be remembered that often they must be modified to meet the need of individual cases.

Several illustrations of standard positions which are not shown elsewhere in the manual are here grouped together.

These are the only parts of the body which the x-ray manipulator should be allowed to examine. All other examinations require the personal attention of the roentgenologist.

DANGERS AND PROTECTION

Dangers from the X-Rays.—The danger to the skin of operator and patient requires careful consideration in order to avoid serious injury. It is customary to speak of a dose that will cause a slight temporary redness of the skin as an erythema dose. This dose undoubtedly varies considerably according to the age of the patient and to the judgment of the observer as to the extent of redness which may be called "slight."

The skin dose will depend on the following factors:

1. Target-skin distance.
2. Spark gap (voltage).
3. Current through the tube.
4. Time or duration of exposure.
5. Nature and thickness of filter used.

While complete agreement as to what will give an erythema dose can hardly be expected, all will agree that the dose will increase with the duration of exposure, with the current and with the spark gap; and will decrease as distance between target and skin is increased and as thicker filters are used.

It is convenient in this connection to combine the tube current in ma. and the time in minutes, and speak of milliampere minutes, but it *must be clearly understood that the number of milliampere minutes allowable varies with the spark gap.*

Working at a target-skin distance of 20 inches and a 5-inch gap, 45 milliampere minutes may be safely allowed

if no filter is used. For general safety, a filter of 1 mm. of aluminum is advised, and then an increase of about 40 per cent may be allowed—or about 60 ma. minutes may be taken as a safe total to be received by the skin at this gap and target-skin distance. Thus, at 5 ma.—5-inch gap—20 inches—1 mm. al., a total of twelve minutes may be used on one skin area for fluoroscopic examination, *if no radiograph is to be taken.*

If 20 ma. minutes at a 5-inch gap were used in fluoroscopy there remains only 40 ma. minutes for radiographic work. If 40 ma. is used and 10 seconds is required for a negative, only 6 plates could be safely made. On this account it is wise to make fluoroscopic examinations as brief as is consistent with good work and to use intensifying screens in serial radiography.

A very important point to remember is that when using a smaller gap, although the amount of radiation reaching the skin is less for the same current, the exposure required in radiographic work is very much longer. To get the same plate density at lower gaps, the skin risk is greater. Many cases of dermatitis are due to prolonged or repeated exposure with too small a back-up gap for the work in hand.

Be sure that unfiltered rays along the axis of the tube, which do not have to pass through the lead glass bowl, do not reach the patient.

When an erythema dose is reached or approached, an interval of three weeks should elapse before again exposing.

Exposure beyond an erythema dose may be justified when circumstances arise of an unusual nature. But the surgeon or attending physician should be warned by the roentgenologist before such a risk is to be taken.

Protection of the Operator from the X-Rays.—The ele-

ment of increase in the work time makes care in the protection of the operator of extreme importance. Two things are clear in this matter: First, that effects are cumulative; second, that evidence of injury may develop late. Since the demands of the art fix the amount of radiation for specific purposes, the operator can do only three things for self-protection.

1. Increase the distance from the target to any part of his body.

2. Interpose absorbing material between himself and the tube.

3. Reduce the time devoted to the work.

The first of these is applicable in radiographic work only, as in fluoroscopy he must work at close range. The third can have only limited application in a military hospital during war, so the second is the practical method.

The following suggestions are offered in the hope that they may be applied:

1. That in all radiographic and treatment work no direct rays be allowed to reach the operator's body without passing through at least 1/16 inch of lead where lead can be used. Lead glass should have an absorption equivalent to 1/32 inch of lead.

2. That in addition to this lead protection, the operator keep several feet from the tube in treatment and heavy radiography.

3. That in using either a vertical or a horizontal fluoroscope, a careful test be made to ensure that no direct rays come through bad joints, holes in lead, or other unprotected openings.

4. That the fluoroscopic screen be protected with lead glass at least equivalent to 1/32 inch of lead.

5. That the lead glass and sheet lead on the frame overlap at least ¼ inch.

6. That the diaphragm never be opened or moved so as to send part of the beam past the screen, and 1 mm. of aluminum be used as a filter in all cases.

7. That in horizontal fluoroscopy some protection be given for rays scattered at right angles to the patient's body.

8. That the operator study his working conditions so as to secure the results required in the minimum time.

Under no circumstances should an operator use any part of his body for fluoroscopic demonstration, nor should he hold any plate or dental film in position during exposure.

It should be understood that the final responsibility for protection, both of the patient and the operator, rests on the roentgenologist himself, and after his apparatus is installed he should not neglect to test for gross leaks and insufficient protection.

The fluoroscopic screen in a well-darkened room will help to find where danger may lurk but gives no idea of the amount of radiation involved in the indicated directions.

According to the work of Pfahler and others, on a 5-inch gap the number of milliampere-minutes required with unfiltered radiation for a full erythema dose at 20 inches, allowing no factor of safety, will be about 60. This means that without filter, 5 ma., at a 5-inch gap, 20 inches target-skin distance, 12 minutes will almost certainly give a skin inflammation.

A test of the danger may be made as follows: take a few dental films, number them, and place in the position occupied by the operator's body when at work, but attached to his clothing. After he has worked for some time, develop these films and note their general density.

Then using the above data, 5 ma. at 20-inch target-plate distance and a 5-inch gap, expose a series of films for defi-

nite fractions of the time required for an erythema dose. These fractions must be small and care must be taken to develop these films exactly as the test films were developed. In this way it is possible to determine the time the operator must work to approximate an erythema dose. Probably ½ such a dose per month would not have any serious effect.

Electrical Dangers.—In the use of high-power x-ray apparatus, care must be taken to avoid discharge from high tension lines to earth through the body of either patient or operator. Fatal results may follow, and in any event the nervous shock to the patient may be serious. Danger arises from sparks followed by an arc discharge from the high voltage line to the body, thence to earth.

To get such a discharge, we must have:

1. Grounding of patient or contact with badly insulated grounding material.

2. So short an air distance from some part of the high tension system as will allow a break over spark.

A single spark, while disconcerting, is not dangerous to life, but it serves to pave the way for a heavy *discharge from the line* if the supply is maintained. On static machines and most induction coils, body connection so reduces the line voltage as to preclude any fatal amount of current; but with the modern high power transformer it is a different matter.

The danger of an initial spark-over to the body is solely a matter of line to skin distance and voltage from line to earth. When a tube is taking current, the voltage from either line to earth is less than it would be on the same control setting if no current were passing. Hence, failure of the tube to take current at any time tends to cause discharge to the patient. The following are the common ways in which this may happen:

1. Failure to complete high tension connection.
2. "Cranky" gas-tube.
3. Failure to light Coolidge filament before turning on high tension.
4. Break or disconnection of Coolidge filament circuit while running.
5. Attempting to pass current through Coolidge tube in wrong direction.

Another cause for spark-over is the high tension surge often caused on closing the primary switch of the transformer.

Keep all high tension lines at least twice as far from any portion of the patient as the working spark gap. Thus, if using an equivalent gap of 6 inches, allow no wire closer than 12 inches. A grounded metal or conducting screen *between* the high tension lines and the patient is complete protection for the patient; thus, a horizontal fluoroscope with a grounded frame is safe with the tube below; but when the patient is between the high tension line and a grounded metal or conducting table, danger is greatly increased.

Type of Control.—Much has been said of the relative danger with various controls. Simply stated it amounts to this: the rise in voltage when the tube fails to take current is very much greater on a resistance control (See Figs. 19 and 20), so that the chance of an initial spark is greater; but after such a spark, the chance of a following arc is reduced by reason of resistance in the primary circuit.

With autotransformer control, or operation without resistance—i. e., with rheostat all out—the rise in voltage on open circuit is less; but if an arc *is* started, it is very dangerous. A quick-acting, over-load primary break is very desirable.

Resuscitation from Electric Shock or Asphyxiation.—The prone pressure method of artificial respiration, devised by Prof. Schaefer, of Edinburgh, has been advocated as the most effective method by the United States Bureau of Mines' Committee. This method can be used with oxygen inhalator. It should always be used immediately to resuscitate asphyxiated persons and kept up continuously until approved mechanical resuscitating devices are

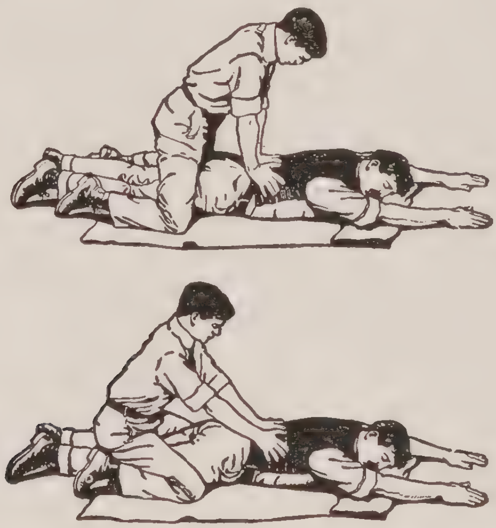


FIG. 95. Resuscitation from electric shock. Above—Expiration, pressure on. Below—Inspiration, pressure off.

brought to the scene and adjusted on the patient. Heart stimulant should be given as frequently as necessary.

This system can be used in cases of electric shock, after the victim has been removed from the live conductor, in cases of gas poisoning or asphyxiation from any cause. *Artificial respiration should be begun promptly, as life persists only a few minutes after breathing stops.*

Quickly feel with your finger in the victim's mouth and throat and remove any foreign body (tobacco, false teeth, etc.), then begin artificial respiration at once. Do not stop to loosen patient's clothing; every moment is precious.

Lay the subject on his belly, with arms extended as straight forward as possible, and with face to one side, so that the nose and mouth are free for breathing. Draw forward the subject's tongue.

Do not permit bystanders to crowd around and shut off the air.

Kneel, straddling the subject's thighs and facing his head; rest the palms of your hands on the loins with thumbs nearly touching and with fingers spread over the lower ribs. Fig. 95.

With arms held straight, swing forward slowly, so that the weight of your body is gradually brought to bear upon the subject. This operation, which should take two or three seconds, must not be violent, lest internal organs be injured. The air is thus forced out of the lungs.

Now immediately swing backward so as to remove the pressure, but leave your hands in place. The air thus enters the lungs.

After two seconds swing forward again, repeating this operation twelve to fifteen times to a minute, a complete respiration every four or five seconds. While this is being done, an assistant should loosen any tight clothing about subject's neck, chest or waist.

Continue artificial respiration (if necessary) two hours or longer, without interruption, until natural breathing is restored. Even when natural breathing begins, carefully watch that it continues. If it stops, begin artificial respiration again.

Keep subject warm by applying a proper covering or artificial heat, hot water bags, etc.

Do not give stimulants or liquids by mouth until subject is fully conscious.

FLUOROSCOPY

Definition.—*Fluoroscopy* is the method of making studies of opaque objects by means of the x-rays and the fluorescent screen. It depends upon the fact that under the influence of the x-rays certain substances become highly fluorescent. The fluorescent screen consists primarily of a thin layer of this fluorescent substance spread upon cardboard. This cardboard or fluorescent screen in turn should be covered by lead glass having an absorbing capacity equivalent to 1/32 inch of lead, and mounted in a frame. To this frame there should be attached convenient handles, and these handles should be so arranged that the hands will be protected from stray rays during the examination. When not working in a well-darkened room the screen must be covered by a hood so as to shut out other light. This hood is usually arranged in a pyramidal form. The depth of this pyramid must be at least the average focal distance for the eyes.

A fluoroscope for use in a lighted room has been described by Dr. Dessane (Gallot et Cie),[1] Figs. 96 and 97. A spring attached across the hinge line will hold the fluoroscope down in its working position, or when tilted over it will be held by the same spring in position on top of the head.

Apparatus.—If the apparatus is to be used solely for fluoroscopic work the exciting outfit needs to be capable

[1] Described by L. Ombredanne et R. Ledoux-Lebard, ''Localization et Extraction des Projectiles,'' Libraries de L'Academie de Medicine, Paris.

of producing no more than 5 to 10 milliamperes with a voltage corresponding to from 3-inch to 6-inch parallel spark gap. A coil run by a mechanical interrupter will give very satisfactory x-ray light for fluoroscopic work.

The great bulk of fluoroscopic work in military hospitals will be done in the horizontal position. It will be the position most desirable for the localization of foreign bodies,

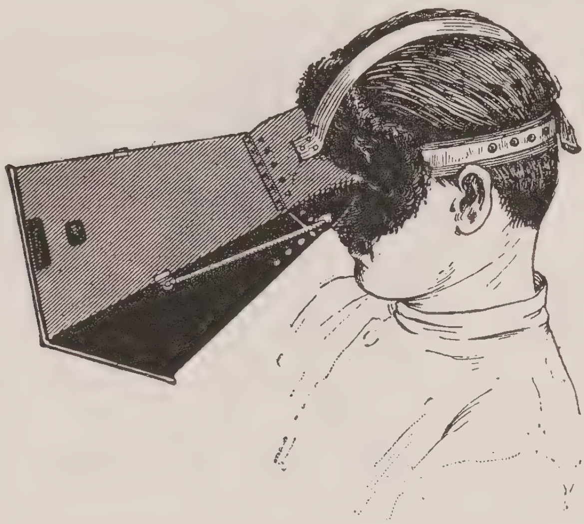


FIG. 96. Dessane's fluoroscope attached to the head ready for examination.

the study and manipulation of fractures and of the stomach and intestines.

An outfit for *vertical fluoroscopy* is also desirable in military work. Its greatest use will be in the study of cavities containing fluid, such as cavities in the lungs, accumulations of fluid in the pleura or the study of opaque fluids placed in the stomach and intestines to render them opaque and visible. In this vertical position one can often obtain the upper level of fluid and make an absolute diagnosis of a condition that, when studied in the horizontal position, would give less evidence leading to a correct diagnosis.

Operating Switch.—This switch should be adjusted: (1) so that the operator need not continuously stand on one leg; (2) so that it will accurately and quickly close or open the primary circuit; (3) and so that it will turn on and off the ruby light which is used for general lighting of the fluoroscopic room. (See page 177.)

The Darkroom, Importance of Absolute Darkness.—Too

Fig. 97. Dessane's fluoroscope elevated to the top of the head after the fluoroscopic examination has been made permitting the operator to see by ordinary light without losing the sensibility of the retina because of a ruby glass which automatically drops in front of the eyes as the fluoroscope is elevated.

much emphasis cannot be laid upon the necessity of absolute darkness, especially if an open screen is to be used. The success in attaining absolute darkness will depend in great part upon the ingenuity of the operator. Black cloth or black paper is a cheap way of rendering cracks and light fissures dark. To cover windows and other openings, double black curtains running in grooves will be found the most satisfactory. Unless the room be absolutely dark the object under study will be dim in outline and in many instances not even visible. Lack of at-

tention, therefore, to this detail may result in a prolongation of the fluoroscopic study, waste of time, injury to the patient and operator, nervous annoyance and very often absolute failure in the ultimate object of the work. If the room cannot be darkened, one must use the hooded screen or work at night.

Ventilation of the Fluoroscopic Room.—See ventilation of developing room, page 125.

Time Required for Sensitizing the Retina.—This will vary with the individual, and particularly with regard to the age of the individual, for the young can respond to this test more quickly than older people. In general, one should be in the dark for 10 to 15 minutes before beginning fluoroscopic study. If one begins in less time than this, there is likely to be unnecessary exposure of patient and operator, and inefficient and unsatisfactory results obtained.

The Light for the Darkroom.—In general a ruby light is recommended on the theory that the retina becomes fatigued by the ruby light and is therefore more easily capable of appreciating the greenish white light of the fluorescent screen. It is most important, however, that so far as possible the dim lighting of the room should be well diffused.

Conditions for Fluoroscopy.—It must be clearly recognized that the illumination on the fluoroscopic screen is entirely of local origin and that the relative luminosity is low. For this reason it is absolutely necessary, in order to observe the details on the screen—that is, the differences in illumination—to exclude light of every kind which does not originate in the excited portion of the fluorescent material. The *visibility* of a shadow on the screen increases with the difference of illumination between the shadow and its immediately adjacent brighter

surroundings, and decreases with the *general* illumination of the screen. As a parallel we may mention the case of lantern slide projection, where line drawings, heavy markings, and things of great contrast and reasonable size may be projected satisfactorily in a moderately lighted room with a comparatively low power lantern. But when finer details are to be seen and more difficult gradations to be identified, it is desirable to increase to some extent the candle power of the projector and to exclude light from every source, such as windows, doors, etc., which has not passed through the optical system to produce the image. This principle is of even greater importance in fluoroscopic work because the small crystals excited to fluorescence emit light in every direction and always tend to illuminate portions of the screen which may have received no x-rays, so that we get a local cross-fire of true light spreading along the screen, reducing to a great extent the visibility of shadows. Screens will differ in this respect to some extent according to the size of crystals used and the smoothness of the surface.

On account of this diminution of detail, owing to the nature of the screen, it becomes of increasing importance to secure as sharp shadows as possible by the use of a fine focus tube and by working at a suitable screen distance.

It should again be mentioned that the degree of contrast, irrespective of the illumination, is controlled exclusively, for a given target-screen distance, by the equivalent spark gap of the working tube. The contrast will be higher the less penetrating the radiation, and, therefore, the lower the spark gap consistent with proper illumination.

At a given spark gap the only effect of increasing milliamperage through the tube is to increase the average illumination on the screen, so that contrast must be con-

trolled by spark gap, and brightness alone may be in part controlled by variation of the tube current. The effect of scattering is even more disastrous in fluoroscopic work with thick patients than it is in radiographic processes.

As regards the preparation of the retina for fluoroscopic work, undoubtedly the ideal is to have the roentgenologist remain in total darkness for 10 minutes before starting work, and to remain in as nearly complete darkness as is possible continuously during the period of fluoroscopic examinations. It is, however, often necessary to make a fluoroscopic examination in the ward or operating room. Of various eye screening methods which have been suggested, the most generally recommended is undoubtedly the bonnet fluoroscope, which will be provided for use in our operating rooms.

For work in the wards there will be supplied a type of automobile goggle in which celluloid instead of glass will be used. For comparatively dark weather, or when working in the evening with artificial light, the red celluloid will probably be sufficient, but for ward work when there is bright sunlight it is desirable to reduce the intensity still further. The operator can then insert the green celluloid piece back of the red, so obtaining an intensity and quality of light reasonably well suited to the purpose. As celluloid is not breakable, and the goggles can be fitted close to the eye it seems to serve the purpose reasonably well.

In working with the surgeon it is absolutely necessary that *one* party keeps his eyes in condition for the best fluoroscopic vision. However commendable the desire on the part of the surgeon to see for himself, he should clearly understand that his selection of surgery as a vocation has not modified his optical organs so that he can see without taking the same precautions in fluoroscopic work

as are prescribed for the x-ray operator. It, perhaps, ought also to be mentioned that for a person who is partially green blind fluoroscopy with the ordinary screens is quite impossible, and men having this visual defect ought not to attempt work in this field.

Summarizing, we may say that fluoroscopy demands (1) control of both voltage and current in a tube wherever possible, (2) a fine focus tube, (3) as small a diaphragm as possible, (4) a good screen, and (5) eyes sensitive to screen light by preparation in the darkroom, or near darkroom, for a sufficient period to insure good vision.

Note that one accustomed to using eye glasses for reading should not remove them when doing fluoroscopic work, as the necessity for clear vision is even greater than in other cases.

If these conditions are attained with reasonable care, many things can be determined with the fluoroscope much more quickly than with plates, and the information secured will be as accurate. The x-ray operator should read carefully the chapter on protection, and must assume responsibility for his own safety.

LOCALIZATION

General Considerations.—In order that this important work may be done expeditiously and with the desired degree of accuracy, it will be quite important for the roentgenologist to consider the matter from the standpoint of the greatest service for the minimum effort, and with the fullest consideration for the patient.

Where the work is largely fluoroscopic the roentgenologist must insist on having a properly darkened room and be allowed to remain therein in order to keep his eyes in proper condition for his work. It is intended that the patient should be prepared outside of this room, being placed upon the stretcher top of the x-ray table, and that the necessary examination which precedes the work of the roentgenologist should be done in daylight and all necessary information for his guidance transmitted to him in some convenient form. Before any patient is placed in position he should see that the apparatus is in satisfactory working condition, that the accessories necessary for the localization he intends to make are conveniently at hand, nor should he fail to train his assistants during slack periods in order that they may act promptly and efficiently.

After the patient is placed on the table it is desirable to bring the affected part which is to be examined somewhere within the middle third of the movement of the tube box. A rapid, but nevertheless careful, survey should

be made of the regions at some distance from the point of entrance and emergence of the projectile, as it is well known that projectiles often follow tortuous paths, and are at considerable distances from the point of entry, and very often split into fragments, each of which may take lodgment in points remote from the main path.

Having located the projectile whose presence is sought, it will often be found that by use of parallax, on moving the tube slightly, one can readily determine whether the projectile is above or below certain bony landmarks, and sometimes a slight manipulation of muscle will indicate position with reference to important soft tissues.

In the discussion of methods of localization following, an effort has been made to think out and test out in the laboratory the necessary steps, in order that no essential feature may be omitted, and that the minimum of time should be required in completion of the operation. It is not intended that such instruction should be blindly followed or that the roentgenologist should be prevented from developing a procedure which his experience proves efficient or desirable, but it is hoped that the steps, as laid out, will furnish a working guide for the beginner, and may be suggestive in the hands of the more experienced roentgenologist.

Care in Marking and Recording.—Inasmuch as conference between the surgeon and the roentgenologist is likely to be the exception rather than the rule in military radiology, great care must be taken in recording observations. In addition to the written report, we must, in the case of multiple foreign bodies, identify each skin mark and the corresponding depth. This may be done in either of two ways: One may number each dot on the skin and write a depth number beside it. There is some danger in this case of confusing the depth of the projectile with the

localization number. The following is suggested as an alternative:

Place around each skin mark an indicating symbol that also appears on the record, as indicated in Fig. 98.

The numbers signify that 8 cm. below the dot in the circle there is a projectile; 3 cm. below the dot in the square there is another; and so forth.

Reports.—Reports may be made in part on anatomical charts, if these are available. The written portions should be brief, but exact and explicit.

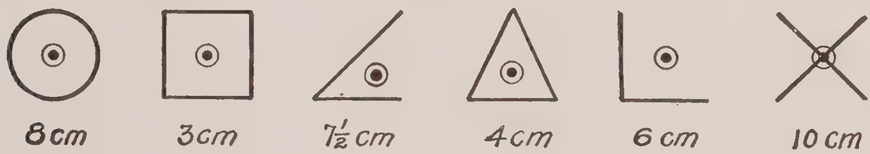


Fig. 98. Method of distinguishing between skin marks and denoting depth of foreign body from skin marker.

They should include:

1. The designating symbol and the depth, *corrected* for screen position.
2. The approximate position of the patient when examined.
3. Anatomical information.
4. Approximate size of projectile.
5. Condition of injured bones.

For marking the skin in connection with localization operations, it has been found that the Finzi ink meets a majority of the tests better than any of the others tested. The formula of this ink is as follows:

Pyrogallic acid	1.0 gm.
Acetone	10.0 cc.
Liquid chloride of iron	4.0 cc.
Wood alcohol	q.s. ad 20.0 cc.

This ink is rather thin; it can be used with a pen, but is not very satisfactory in this respect. It makes a black mark and dries in from thirty to forty-five seconds, depending on the amount used. It will smudge slightly during the first fifteen minutes after applying, but leaves a permanent mark. The color carries from gray to intense black according to the amount used. It is visible for forty-eight hours to a week, depending on whether it is subjected to rubbing in contact with solid objects or with clothing, etc. It can be seen through iodine stain and resists alcohol. The standard skin inker will make from ten to twenty successive marks without replenishing.

With proper care as to the amount to be taken on the wick, this ink will be found to give satisfaction in use. Too much ink will cause the mark to run into the surrounding skin crevices, and the center of the mark will not be easily gauged. Too little ink will not make a sufficiently black or permanent mark.

Standard Methods.—Experience in military service during the present war has served to emphasize the importance of rapid and reasonably accurate methods for the localization of foreign bodies. The ordinary practice of roentgenology, as a rule, has little to do with this phase of the subject. In civil practice methods could be used which required a considerable amount of time, and it was usually possible to consult with the surgeon and to repeat observations to an extent quite impossible in the present emergency. The localization of small projectiles in the eye had been developed in quite a satisfactory manner and no distinct improvement therein has been attempted. During the war abroad a variety of methods and appliances have been used and the choice of method has been left largely to the individual operator, since circum-

stances prevented systematic attention to either mechanical equipment or special training.

According to the reports received from several excellent surgeons in active service at the front, it would be desirable, and may even be regarded as necessary, that all of the injured should have the benefit of an x-ray examination; since it has been found that there are many cases where foreign bodies split off after entry, or are in such unexpected or peculiar positions that they can hardly be successfully handled without the evidence available from such an examination.

In order to work on such an extensive scale it is necessary to consider very carefully the relation of x-ray work to surgery, and to analyze the methods which are to be employed with reference to simplicity and certainty, and to pay particular attention to the reports and information needed by the surgeon in order to facilitate his work. In this connection it may be remarked that there is a distinction between the x-ray requirements in evacuation hospitals and base hospitals. In the former, speed is essential and simple apparatus must suffice. In the latter, a more complete equipment would be expected. It may be well to recognize that time will not permit the use of plates or films in the evacuation hospitals, and dependence must be put almost entirely upon fluoroscopic work. Consequently, all arrangements in hospitals near the front must conform to the conditions imposed by fluoroscopy.

As regards the methods that have been selected, it is not claimed that they are original, and no effort has been made to get any universal or entirely new procedure. After consideration of many methods it has been deemed wise to limit selection to those that best meet certain requirements. Among the desirable features more or less well met by various methods we may mention:

1. The apparatus required should be simple.

2. The manipulation should not require an undue amount of skill.

3. The time required should be a minimum consistent with reasonable accuracy.

4. All operations likely to lead to error must be excluded.

5. The comfort of the patient should be considered.

It must also be remembered that the operator is an essential part of the localizing apparatus. It is therefore necessary to devise methods which will relieve the operator of computation and thus reduce the chances of error, especially when an enormous amount of work is to be done under trying conditions. Among the operations giving opportunity for error even in ordinarily competent hands we may note:

1. Reading of fine scales.

2. Reading any scale in bad light.

3. Making arithmetical computations.

4. Drawing diagrams.

5. Changing from bright light to read scales and back to fluoroscopic work.

Attention has therefore been directed to such accessory devices and organization of steps as would tend to eliminate these contributing sources of error.

In limiting the number of methods for which provision is made there is no intention of denying that others may be equally useful and accurate, and it is no criticism of the methods or their advocates that they have not been selected. It was deemed more desirable to have a few methods for which careful provision had been made and in which men could be well drilled, but it is entirely optional with the roentgenologist which method he will use in any given case. It would be impossible to provide apparatus for all

the methods that might have been proposed or advocated.

Reference to the standard methods has been made by letters instead of by the names of those responsible for their development. This is not done with any idea of detracting from the credit of the authors or of indicating novelty, since no claim of priority is made or desired, but simply because descriptions vary in the literature and might be quite confusing to the reader who tries to follow directions that do not apply to our apparatus.

Before discussing the various methods in detail, it may well be pointed out that refined mathematical accuracy is not generally a requisite for good service in this connection. As was remarked by Lieutenant Colonel James T. Case, Senior Consultant in Roentgenology of the American Expeditionary Forces, "This war is not being fought with bird shot, and a localization, as a rule, to ½ cm. will be entirely satisfactory." In a few cases—such as bodies in the eye, or where a small foreign body is in a particularly dangerous and troublesome place—greater accuracy may be required, but it is necessary for the surgeon to keep in mind the fact that because of the incision and the introduction of retractors there may result a considerable displacement of the projectile and it is often difficult to connect its position with displaced skin marks. It may also be remarked that in the majority of cases a definite anatomical localization should be given by experienced and well-trained roentgenologists, which in many cases may be of greater value than a simple depth determination. Whether or not this is well done will determine to a considerable extent the value of the x-ray service, and every opportunity should be given the roentgenologist to ascertain the landmarks used in surgery and to adapt his work to the requirements of the surgeon using his data.

The various localization methods may be divided into two

distinct groups. In the first of these a mark is made upon the skin and the distance of the projectile from this mark is determined. It is generally assumed that the skin mark was made at the place of emergence of the beam which formed a shadow of the projectile and that the tube focus was adjusted vertically beneath the projectile. A vertical line drawn later through the skin point can only strike the projectile if the body of the patient is placed in the same position on the operating table as it occupied during the x-ray examination, and careful distinction must be made between a vertical line so described and a line perpendicular to the surface of the skin at the marked point. The amount by which the surgeon may miss the projectile by failure to get a correct sight line increases materially with increased depth of the projectile and with decreased dimensions, and some idea of the size of the body sought should always be given. Much greater care will surely be needed in the localization of the smaller bodies.

In the other group of methods some material guide is given to the surgeon to assist him during operation. As a rule these require more time, both on the part of the roentgenologist and of the surgeon's assistants. They are naturally better adapted to the work done in the permanent or base hospitals.

After receiving reports from both surgeons and roentgenologists abroad, and after conference with Lieutenant Colonel James T. Case, at which appliances and methods were carefully considered, it was decided by the Surgeon General's Office to adopt and provide apparatus for the following methods:

A. Two wire, double tube shift method.
B. Parallax method.
C. Tube shift method with mechanical triangulation.

D. Profondometer.

E. Hirtz compass with accessory devices.

F. Cannula and trochar with harpoon.

It happens that the first three of these are simple depth measurements, although *B* may give more than one depth, whereas the last three may be used to give more or less definite guidance to the surgeon during operation.

It is assumed that the majority of the work will be done with the standard x-ray table by fluoroscopic methods and with the tube below the table. The tube box is movable in two directions as in the usual trochoscope and is provided with a double shutter giving a diamond-shaped opening with the diagonals parallel and perpendicular to the length of the table and also with an adjustable slit, under separate control, parallel to the length of the table. The tube box runs freely and may be locked in any position against both lateral and longitudinal movement, and is also provided with a simple means for fixing the amount of tube shift for a particular purpose or for measuring any shift from a fixed position.

The fluoroscopic screen is carried by a ball-bearing carriage mounted on the table rails, and provision is made for a movement parallel to the table, for rotation about a vertical axis and, also, for a vertical shift. Each of these movements may be prevented by a suitable, convenient lock. The fluoroscopic screens are perforated with a small hole through which a marking device may be inserted to mark the skin in the vertical ray. When this ray is spoken of it is assumed that the table will be substantially in a horizontal position and that a line joining the target with the center of the diaphragm will be perpendicular to the plane in which the tube may move. The opening in the screen also serves a very convenient purpose in temporarily fix-

ing in position the scales and other pieces of apparatus which it is desired to use on the fluoroscopic screen.

Definitions—

Central Ray.—The ray passing through the center of the limiting diaphragm, which, when the tube is fixed with reference to the diaphragm holder, will change its direction with each tilt or movement of the tube and its mounting.

Vertical Ray.—The central ray when the tube is beneath the table, and the target is so adjusted that the line joining the focal spot of the target with the *center* of the diaphragm opening is vertical.

NOTE.—There has been a good deal of discussion with reference to the correction for depth on account of the thickness of the glass over the fluoroscopic screen. As outlined in this manual, there is only one case where this correction is of any importance or even applies. In *Methods A* and *C* it should be remembered that the eye of the operator is directed at the shadow *on the screen* and that the distance measured on the lead glass in *Methods A* and *C* represents a length on the screen itself so that when the screen is in contact with the marked point on the skin we may, in *Methods A* and *C,* ignore the glass thickness.

In case, by reason of curvature of the body, the horizontal screen cannot be brought in contact with the skin mark, it will be necessary to allow for the distance between the screen and the skin, and this may be a very decided correction. The simplest way in which this may be done is undoubtedly to push the graduated marking device which is used with the perforation in the screen through to contact with the skin, grasp it at the surface of the screen with the thumb and forefinger and immediately on withdrawal read and record the distance from the glass surface

to the skin. This would give a depth, not below the screen, but below the top of the lead glass. Since this glass is generally about one-half centimeter thick it will suffice to use one-half centimeter or one division less than is actually measured as a subtractive correction.

In *Method E,* when the Hirtz compass is used fluoroscopically, care must be taken to *add* to the depth measurement of the projectile the thickness of the lead glass, if the method of determining marker depths through the hole in the screen is used. In other words, in the Hirtz compass, the four depths must all be measured from the same plane, although this is not the plane of the arms when the compass is set up.

Method A.—Probably the most generally used fluoroscopic method is that designated in our work as *Method A.* This method was proposed since the beginning of the war by Professor Strohl of the French Roentgenological Service. It is extremely rapid, reasonably accurate, and, as it requires a minimum of manipulation, it is likely to be the method of preference for work in the evacuation hospitals. In this, as in the other methods here described, it is assumed that the standard apparatus adopted by the x-ray division of the army will be used.

The apparatus supplied for the standard equipment includes a substantial brass frame, carrying two wires firmly attached across two opposite corners and protected by a thin sheet of aluminum, Fig. 99. These wires move with the tube box and, when the diamond-shaped shutter is wide open, they would cast shadows upon the fluorescent screen. These shadows, of course, move with the tube box. After bringing the shadow of the projectile to the center of the fluoroscopic screen, and marking the skin through the opening provided, the operator places in position a small celluloid scale with two sliders. He then shifts the tube

until the shadow of one of the wires carried by the box coincides with the now displaced shadow of the projectile, and adjusts one of the sliders to mark this position; then,

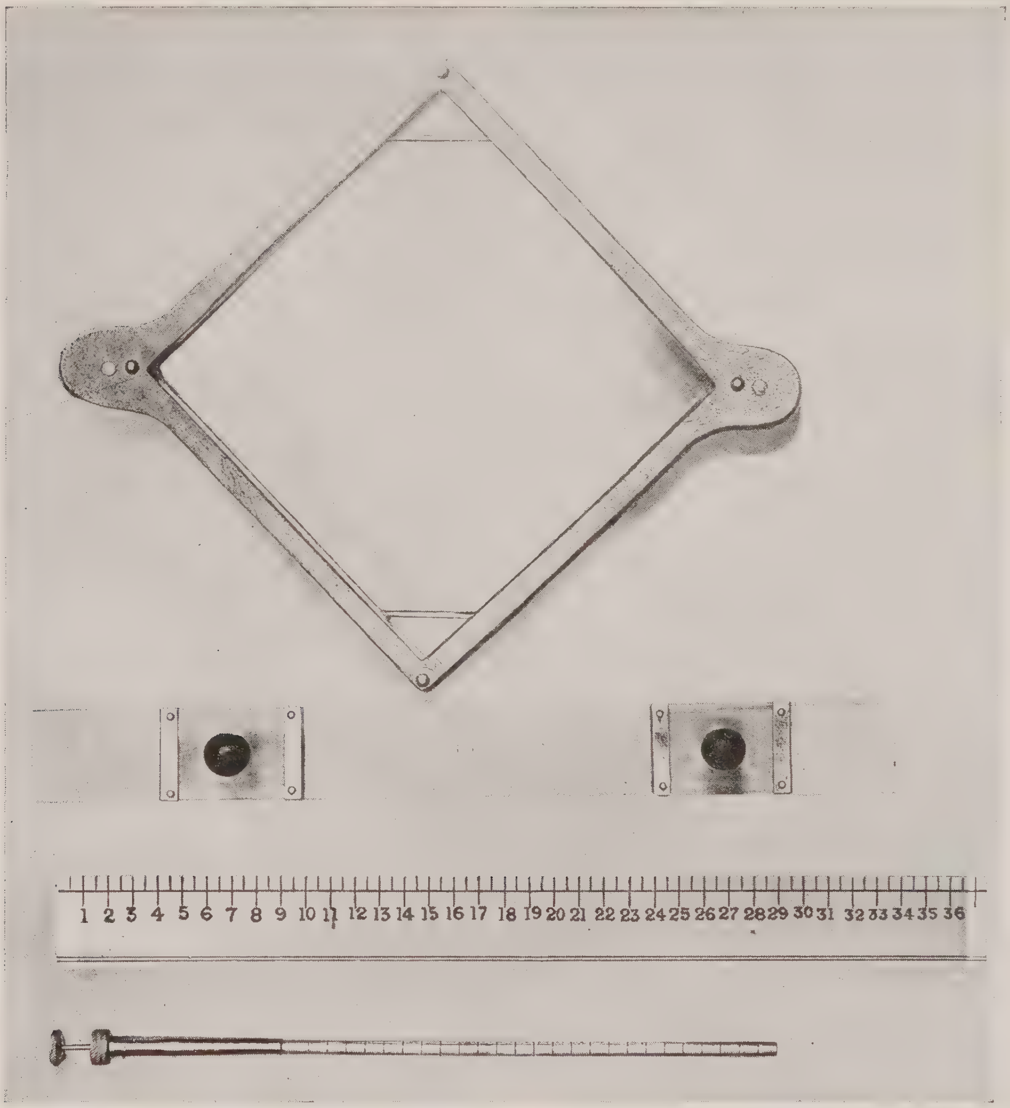


FIG. 99. Apparatus for *Method A* consisting of cross wire holder, double slider, and special rule.

shifting in the opposite direction, and leaving the first slider and the center of the device fixed, the shadow of the other wire is brought to coincidence with that of the

projectile, and the second slider fixed accordingly. The distance between these two markers is in a definite proportion to the distance from the fluoroscopic screen to the projectile in question, and by means of a properly designed scale the depth in centimeters and fractions of a centi-

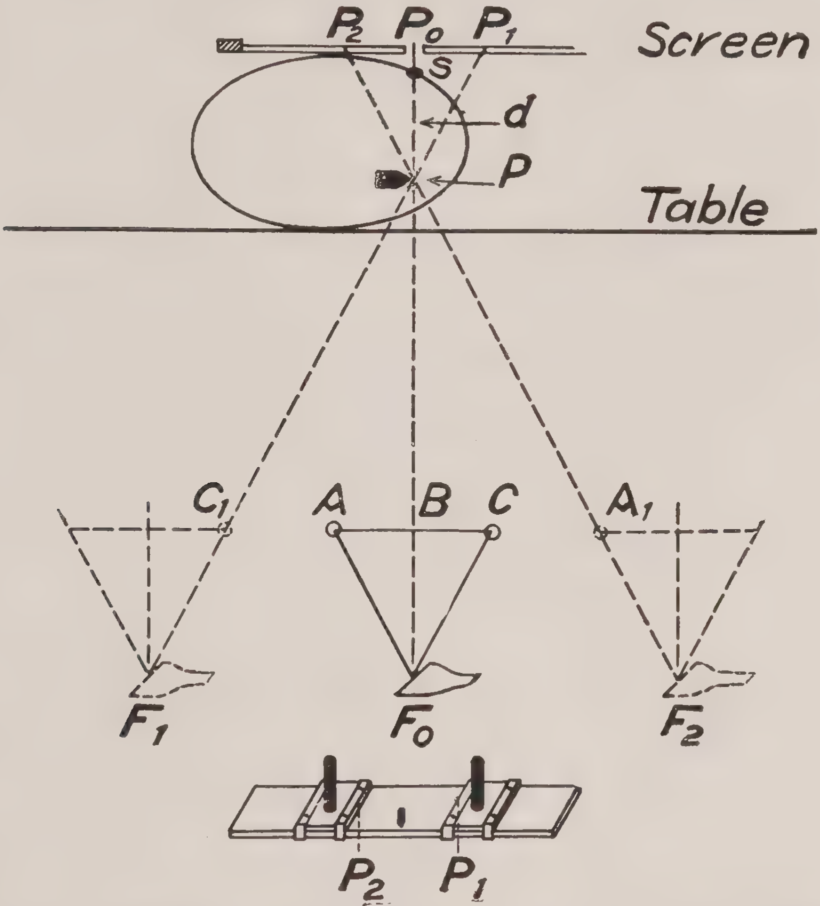


FIG. 100. Principle of the *Method A* above. Simple slider for measurement of the distance between the two images shown below diagram.

meter can be read directly. In case the central point of the screen is not in contact with the skin, where a mark is made, it will be necessary to correct for the distance between the skin and the screen. This is not necessary when the point marked is actually in contact with the horizontal screen.

On account of its extreme simplicity and the fact that only a single measurement has to be made, and that the target-screen distance need not be known, this method has been placed first in order of preference.

The principle of method A is illustrated by Fig. 100, which shows a vertical section through the foreign body P, and the target focus F_0. B is the foot of a perpendicular from F_0 on the line AC. A and C are the two metal wires rigidly attached to the tube box and equidistant from B. Let P_0 be the shadow of P by the vertical ray. If we shift the target parallel to the screen and to the left, both A and C being fixed to the box, they must move with it and at a certain point F_1, C_1 and P will fall on the same line, and the shadow of C in the position C_1 will coincide with that of P at P_1. Likewise, shifting the target to the right will bring A_1, F_2 and P into the same straight line, F_2PP_2.

Since F_1P_1 is parallel to F_0C,
F_2P_2 " " " F_0A,
and P_2P_1 " " " AC,

the triangles F_0AC and PP_1P_2 are similar. Consequently P_0P = depth of P below $P_0 = d$, is in the same proportion to P_1P_2 as BF_0 is to AC. Or we may write,

$$\frac{\text{Depth of projectile}}{\text{Image shift}} = \frac{\text{Height of } B \text{ above } F_0}{\text{Distance between } A \text{ and } C}$$

The latter ratio is constant and is fixed in the set-up on the regular army x-ray table.

Hence d = image shift multiplied by a constant, k, that is

$$d = P_1P_2 \times k.$$

If we read P_1P_2 in centimeters and multiply by k, d will be found in centimeters.

The special sliding markers, described above, are shown

in Figs 99 and 100. The center pin drops into the hole in the lead glass and prevents slipping.

To avoid multiplication a special scale is provided. The distance, P_1P_2, read on this scale gives the required depth. This scale is *not a centimeter scale,* but the readings give

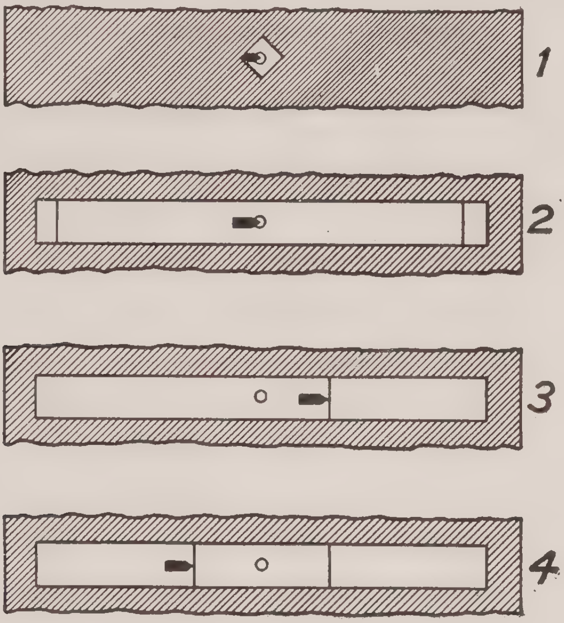


FIG. 101. Successive appearances on fluoroscopic screen in Method *A*. (1) Shadow of projectile with small diaphram at central point of scheen. (2) Rectangular diaphragm replaced by slit opening shadow of wires at right and left. (3) Tube has been shifted to the left, bringng shadow of projectile and right hand wire to coincidence. (4) Reversed shift of tube, bringing left wire and projectile shadow to coincidence.

depth in centimeters and fractions thereof for a proper height adjustment of the tube.

Fig. 101 shows screen shadows in steps of this method. In (1) is seen shadows in central ray; (2) shows open slit and shadows of wires; (3) shows coincidence of shadow and right hand wire, and (4) points for measurement.

Operating Instructions for Method A—

1. Make a general survey of the region tó be examined, noting the number and approximate position of the pro-

jectiles, and the condition of the bones as to fracture or projectile injury, dislocations, etc.

2. Bring the shadow of the projectile which is to be localized, using a small shutter opening, upon the perforation in the screen, and lower the screen until it is in contact with the body.

3. Using the special skin marker, mark the skin carefully through the perforation, and observe whether the skin point is in contact with or at some distance from the under side of the screen. If the latter, immediately note the correction needed.

4. Open the diamond-shaped shutter fully, and close the slit to a convenient width.

5. Insert the pin of the small celluloid double slider in the perforation in the screen, the screen to be locked against all movement. Shift the tube to the right or left, watching the shadows of the cross wire, which is initially seen at the extreme edge of the slit opening, until these shadows become coincident. Leave the tube at rest, and adjust the inner edge of the slider to coincidence with the shadow. Reverse the shift of the tube, and do the same for the second slider.

6. Remove the slider attachment, and, by means of the special boxwood scale provided, read the distance between the inner edges of the two sliders, and record this reading as depth in centimeters.

7. Identify this skin mark, provided more than one localization is to be made, and immediately enter everything on the record.

Method B.—This method utilizes the optical principle of parallax and may be carried out with extremely simple apparatus, although a more elaborate device has been provided. If one observes the shadow of a projectile upon

the fluoroscopic screen, while the tube is moving and the projectile is very close to the screen, the shadow movement for a given tube shift will be very slight and the farther the body is removed from the screen the greater will be the extent of the shadow motion. If we adjust a suitable opaque body outside of the patient until its shadow moves the same distance for a definite tube shift as was moved by the shadow of the projectile for the same tube displacement, the auxiliary body must then be as far from the screen as the projectile whose depth is sought.

In the case of a projectile in the abdomen, so far from the lateral boundary of the body as to preclude simultaneous observation of the indicator shadow and that of the projectile, the adjustment of the latter may be made after the patient has been removed, *provided the screen has been locked against vertical motion* so as to remain at the same distance from the target as before. Generally, however, the indicator may be moved up and down in a plane, passing through the projectile and perpendicular to the axis of the body, close enough to the patient to permit free motion and allow both shadows to be seen at once.

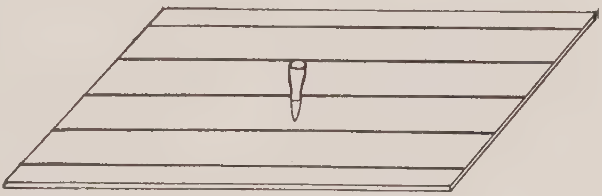


FIG. 102. Ruled celluloid sheet to indicate equality of displacement of two shadows in *Method B.*

By means of parallel lines ruled on a transparent piece of celluloid, Fig. 102, it is fairly easy to ascertain when equality of motion of the two shadows is secured. In the more complete apparatus furnished for this work, Fig. 103, it is possible to mark the skin at the entrance and emergence point of the vertical ray and also along a continuation of the rod carrying the special indicator. This

really gives three independent depths with some corresponding advantage to the surgeon.

The principle of this method is shown in Fig. 104, where

F_0P_0 represents the vertical ray,

P " " foreign body,

B " " an auxiliary body opaque to the rays and adjustable at will.

The shadows of P and B are shown as though they were

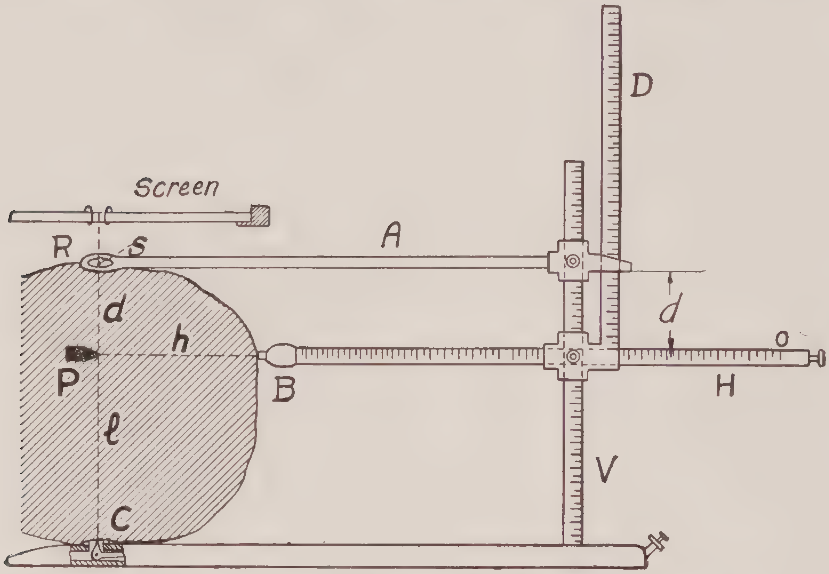


FIG. 103. Schematic drawing of parallax localizer.

in the plane of the paper, but this is not the actual case, as B will be quite outside this plane.

If, now, the target is moved toward the left to F_1, the shadows appear at P' and B', and P_0B' is greater than P_0P' if B is farther from the screen than P.

By raising or lowering B a position may be found where, on shifting the tube, the shadow of B and P move at the same rate. Then B and P are the same distance below the screen. The ruled sheet of celluloid, Fig. 102, is a convenience in making sure that P and B move the same amount when a convenient tube shift is made

Apparatus.—The apparatus may consist essentially of the following parts: Fig. 103.

A base of suitable size carries a vertical post, *V*. Sliding on this post are two rods at right angles to it that may be adjusted vertically at will. The upper of these is not ad-

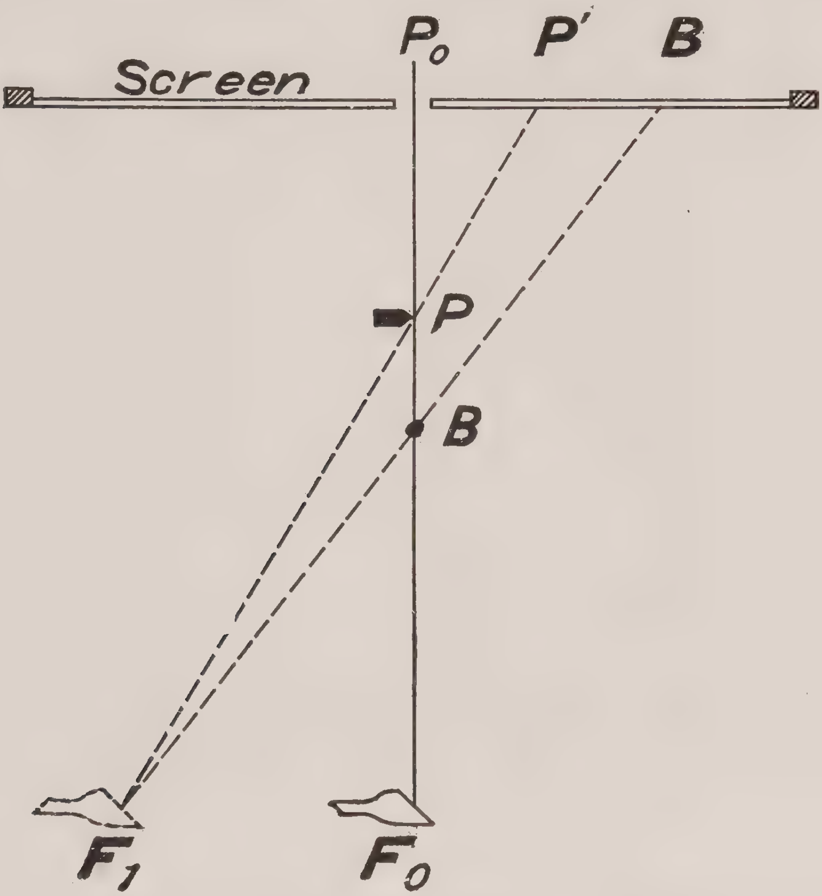


FIG. 104. Principle of parallax method. Auxiliary body, *B*, below *P* and distal from the screen shows greater shadow displacement to *B*.

justable laterally, so that the ring, *R*, is at a fixed distance from the upright, *V*. The other rod carries a ball, *B*. This may be perforated to permit of a projecting skin marker. *B* may be shifted in two directions at will. When adjusted so that its shadow moves at the same rate as that of *P*, when the tube is shifted, the distance be-

tween the rods, d, is the depth of P below the ring, R. This is true independently of the screen position.

By using three scales, D, H, and V, we may find the distance from the skin to P in three directions, viz., PR, PB and PC. In all cases d and h should be observed and R

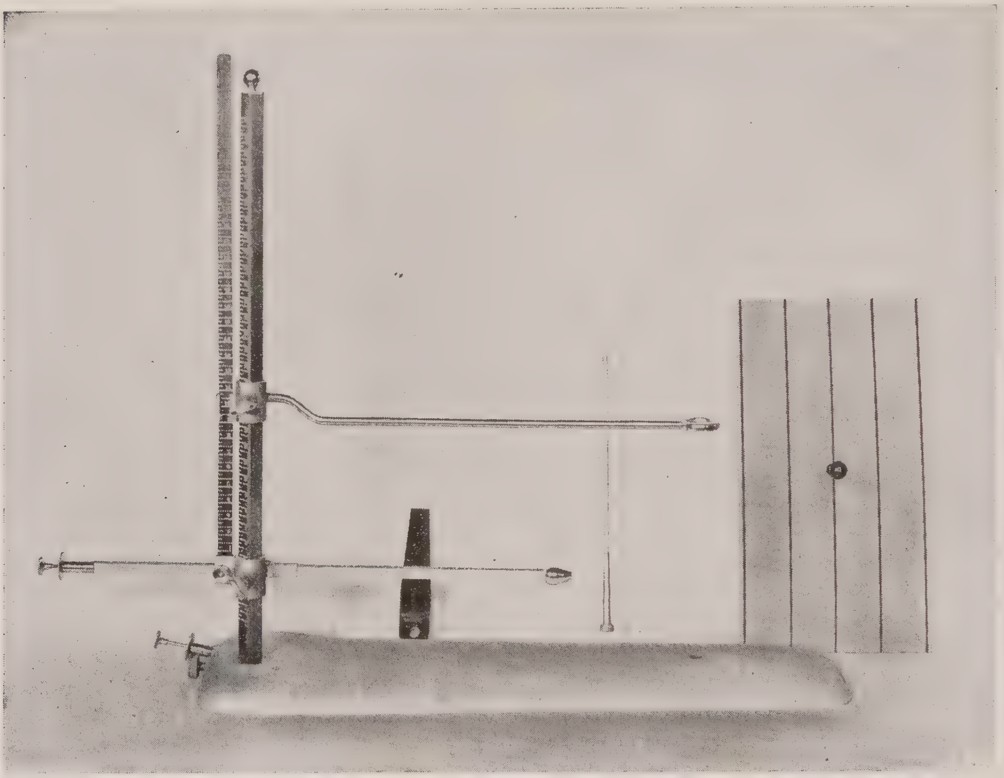


FIG. 105. Apparatus for *Method B.*

and B marked. If the opening in the base, C, is used in centering, RC and PB are at 90°.

The parallax method may be utilized with either improvised apparatus or with the more complete instrument. In using the latter the operator must bear in mind the fact that the accuracy of this instrument will depend to a considerable extent upon the care with which it is used. For example, if either of the horizontal projecting arms becomes bent the readings will be in error, as it is as-

sumed that they are strictly parallel and that both are perpendicular to the vertical support rod. The equipment supplied for use in *Method B* is shown in Fig. 105.

Operation of Method B—

1. Make a general survey as previously directed.

2. Place the parallax instrument in position so that the vertical ray through the projectile falls on the center of the ring. This ring is to be concentric with the one around the opening in the base of the instrument. Have *B* drawn back out of the way when placing the instrument.

3. Lower the ring to contact with the skin and bring the screen down as low as the part examined will permit.

4. Move rod *B* forward as near the skin as free vertical motion will allow, and so place the fluoroscopic screen, if possible, as to allow the shadow of *P* and that of the end of *B* to show on the screen.

5. Place the piece of celluloid, ruled with lines three centimeters apart, so that one of these lines passes through the shadows of both *P* and *B*.

6. Shift the tube until the shadow of *P* falls on another of the ruled lines, clamp the tube in position, and *then* alter the height of *B* until its shadow falls on the same line as that of *P*. Do *not* try to follow the motion of both shadows at once.

7. Check your setting after clamping *B* in position by shifting the tube back, and see whether both shadows fall on the same ruled line as before.

8. Push *B* forward to contact with the skin, and mark by the projecting marker passing through *B*.

9. Carefully remove the instrument, being sure that both horizontal rods are clamped in position, and read the three scales indicating two vertical depths and one horizontal. Record these with the same additional data as in *Method A*.

In using the parallax instrument as described, the depth indicated is from the ring R, which always must be brought down to the skin quite irrespective of the position of the fluoroscopic screen.

Simpler Method of Operation.—In many cases one may utilize a simple substitution method as follows:

Having the shadow in the vertical ray and having marked the skin, shift the tube until the shadow of P has moved a convenient distance on the screen. Lock the tube box in position and register the new shadow position with the edge of a small piece of lead laid on the screen. Lock the screen against vertical motion and to the rail. It can then be swung to one side, the patient moved out of the range of the vertical ray, and the screen swung back to its former position, as determined by use of a small shutter opening. The shutter may then be opened, the marker passed through the perforation in the screen, and adjusted so that the shadow of its lower end reaches the previously placed marker on the screen. Its projection below the screen is the depth sought.

In using the method of parallax it may be inconvenient or impossible to get a good view of the shadow of the projectile and of the adjustable body at the same time. It should be remembered that if the *shift* of the image has been measured, as in the method just described, the patient may be removed without vertical displacement of the screen, and the auxiliary body as B may be adjusted to give the displacement of shadow for the same tube shift, but, in this case, the depth in a horizontal direction cannot be determined.

Method C.—The single tube shift method with triangulation has appeared in a great variety of forms. Some of these involve the drawing of diagrams and the use of algebraic computation. In many cases the apparatus was

designed to work at a fixed tube-screen distance, which has certain disadvantages. The principle of the method is shown in Fig. 106.

Let F_0 be the target in such a position that the vertical ray at right angles to the plane of the tube movement

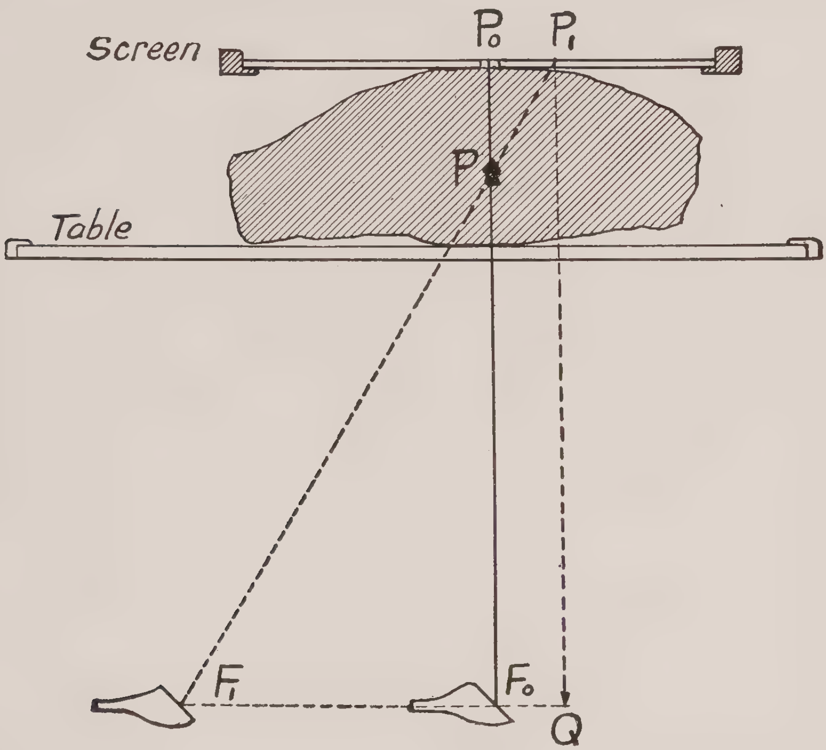


FIG. 106. Principle of single tube shift method.

projects the shadow of the foreign body, P, on the hole in the screen.

Shifting the tube to F_1, there will result an image shift to P_1, and the triangles P_0P_1P and F_0F_1P are similar. Also F_1QP_1 is similar to each.

Therefore $\frac{P_1Q}{F_1Q} = \frac{PP_0}{P_0P_1}$ or $PP_0 = P_0P_1 \times \frac{P_1Q}{F_1Q}$

i. e., depth of foreign body = image shift x target-screen distance divided by sum of tube shift and image shift.

Where no auxiliary apparatus is supplied, one must

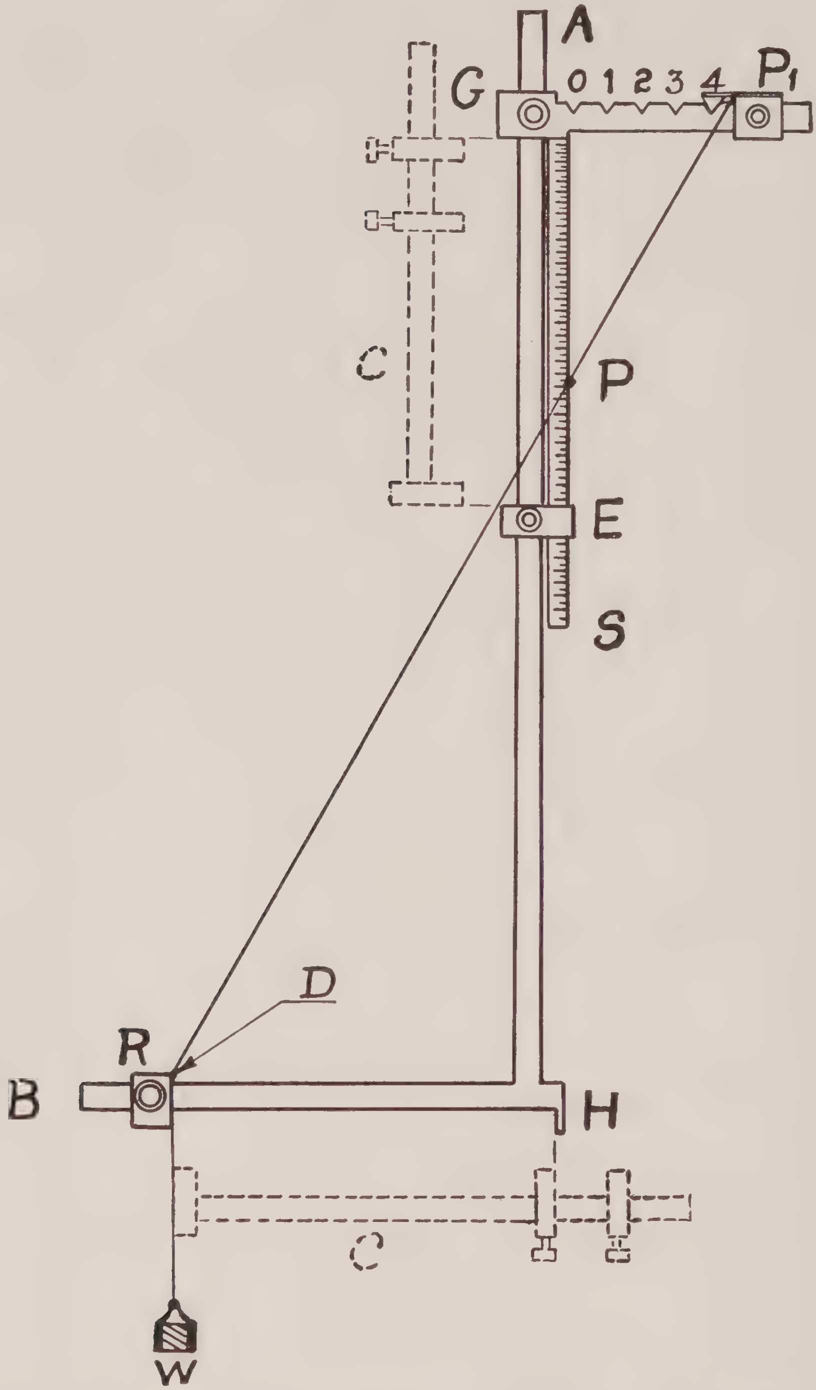


FIG. 107. Wall meter or indicator for tube shift method, also showing method of using adjustable double slider caliper.

measure the various lengths by a scale and make a numerical computation. This may be made easier by the use of special devices.

1. A fixed tube shift of 10 or 15 cm. may be used or an image shift of an exact number of centimeters.

2. A fixed target-screen distance may be used. This is not, however, always convenient.

3. The exact set-up of Fig. 106 may be reproduced by use of a device shown in Fig. 107, which may be supplied in case of a desire to use this method.

This device consists of two straight bars, *A* and *B*, at right angles to each other. *B* carries an adjustable slider, *R*. *A* carries two sliders, *E* and *G*. *E* is not moved after one adjustment unless a new table is used. The slider, *G*, has notches, 1, 2, etc., 1 cm. apart, and a slider, P_1, with a latch engaging these notches. A scale, *S*, with its zero point at the upper end is carried by *G*. A lug at *H* is in line with the zero of *G*.

If, now, DH = tube shift,
GH = target-screen distance,
$P_1 0$ = image shift,

then a straight line, P_1D, will cross the scale, *S*, at the depth of the foreign body below the screen. The instrument should be fastened to the wall in a convenient place and the measurements needed should be made by a caliper, thus avoiding any reading of scales except the final depth.

If in the particular case illustrated, the image shift is 4 cm. and the zero point of scale, *S*, is set above *H* an amount equal to the target-screen distance, and *DH* is the tube shift for an image shift of 4 cm., a string drawn as indicated will cross the scale at a point *P*. The scale reading at this point is the depth sought.

When using the standard table the slider, *E*, is adjusted so that a length measured on the screen-carrier

support will show how much above E we must place G in order that GH may represent the target-screen distance.

It will be observed that this instrument serves to reproduce tube and image positions as actually observed by the roentgenologist; i. e., one vertical ray in which the skin is marked, and one oblique ray whose intersection with the former corresponds to the distance of the projectile from the screen.

An accessory device is also supplied, consisting of a strip of celluloid with a pin centering in the perforation of the screen, and having centimeter divisions clearly marked both ways from the center; making it quite easy to secure an exact number of centimeters displacement.

There is a considerable advantage in making the distance the image is shifted a definite number of centimeters, and measuring the tube shift, since the relative error in measuring the small length of image shift is greater than that in measuring the long tube shift.

When supplied with the accessories indicated above, this method becomes as expeditious as others, and is as accurate as any of the depth methods.

In the single tube shift method there are various procedures which may be used. They all require essentially the same data, namely, (1) tube shift, (2) image shift, (3) target-screen distance. If these distances are measured to scale in centimeters it is possible to compute the end result.

The apparatus supplied for this method includes a scale whereby a definite image shift may be made, if that is desired by the operator. There is also a provision for a definite tube shift of either 10 or 15 cm. on the standard table and for the measurement of any tube shift, if the operator desires to make the shift of the image a definite amount—the procedure generally advised.

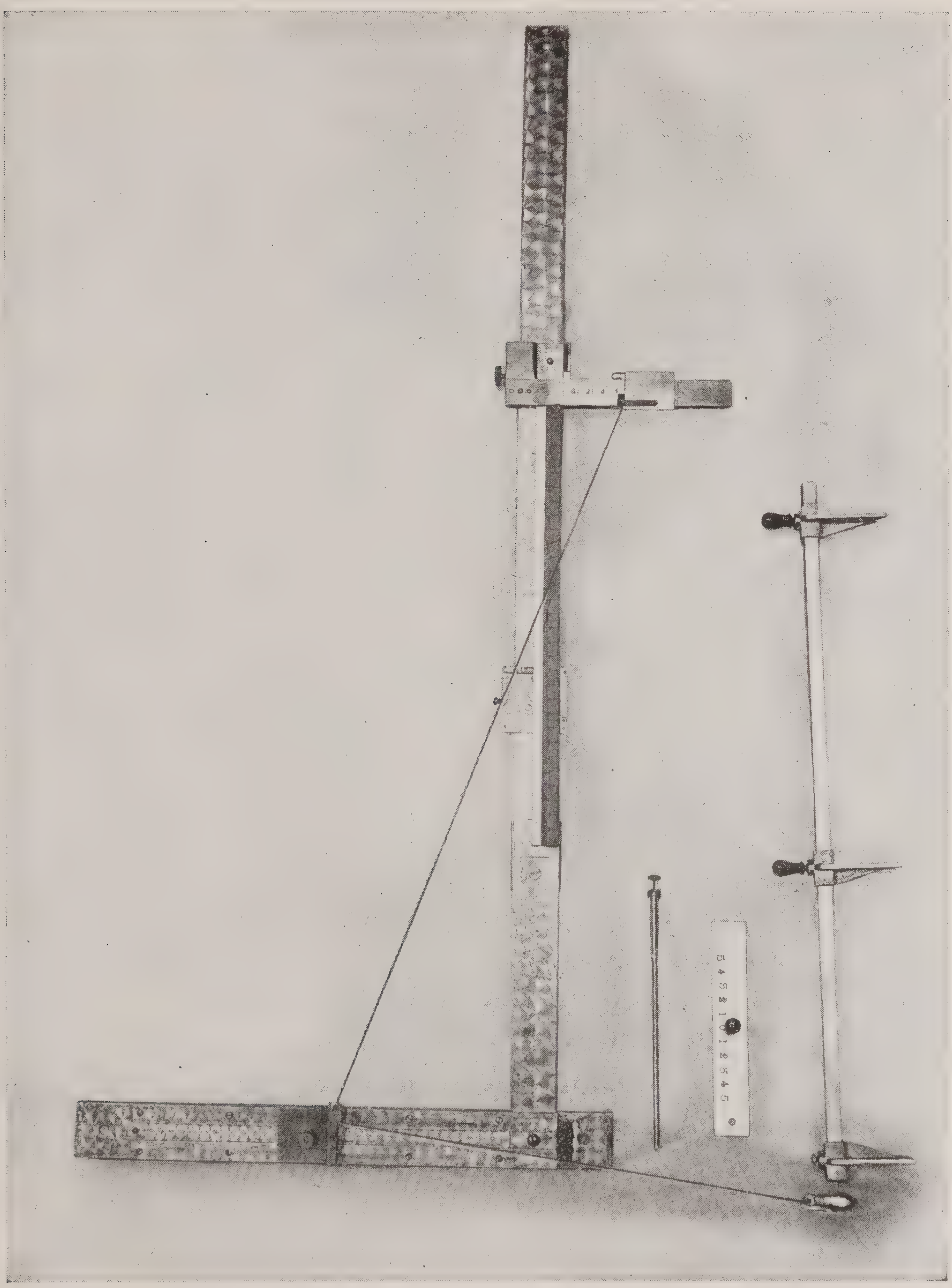


FIG. 108. Apparatus for *Method C.*

The complete equipment, including the reproducing device or wall meter and accessories, is shown in Fig. 108.

Specific Instructions for Method C—

1. Proceed as in other cases with regard to bringing the shadow in the vertical ray to the center of the screen or on the perforation, and mark the skin as usual.

2. Place the small celluloid centimeter scale in position on the screen, so that its length is approximately parallel to the rails of the table. Bring the ring lock, on the rail outside of the carriage, against the projecting stop on the right-hand side, while the tube is in first position. Shift the tube to the left, watching the shadow of the projectile on the scale until it has moved the largest number of full centimeters permitted by full opening of the diaphragm (a narrow slit may be used to sharpen the image), and lock the tube carriage in this position.

3. Having the slider, *E*, on arm *A* of the instrument, previously set according to instructions on page 163, place the outside of the end piece of the caliper, *C*, against the right angle projection on the tube carriage, and slide the inner of the two movable projectors out until it comes in contact with the fixed ring on the table. Then place the fixed projector of the caliper at the top of the tube of the screen carrier, and bring the outside movable piece up to contact with the sliding sleeve, Fig. 109.

4. Move the slider on *G*, Fig. 107, the number of centimeters by which the image was shifted—as four in the figure. Place the inner movable clip of the caliper against *H* and move the slider *R* on *B* to contact with the fixed end and lock in position. Place the fixed end of the caliper on the top of *E* and bring *G* down to contact with the outer slider. A string drawn across, as indicated in the figure, gives the depth of the projectile below the fluoroscopic screen.

5. In case the screen was not in contact with the skin at the point of marking, determine the correction by the usual means.

FIG. 109. Use of double slider caliper in measuring target-screen distance—localization, *Method C.*

If this instrument is used as directed it will be observed that there are no scales to read before the end result and no computations. It is essential that the position of E be determined for the apparatus used and firmly fixed.

All of the second group of methods require somewhat different manipulation and an added amount of data which may give the surgeon rather more definite indications and assist him materially in many cases.

Method D.—This method has been described by Major Joseph M. Flint in *The Military Surgeon* of March, 1917, and while the method is not new in principle it had not been generally used heretofore, as apparatus for its application was rarely available. It consists essentially in securing three lines of sight through the body, each of which is to pass through the projectile. The points where the rays enter and emerge in establishing these lines are plainly marked on the skin. Two pieces of flexible metal, such as a composition of tin, are hinged together in the middle and placed around the body in the plane of the skin marks and made to conform to the shape of the body. The strip is marked, showing the distance that one unhinged end overlaps the other, and the skin marks are transferred to this metal band. Carefully removing the latter from the body, it may be laid down on a card or a sheet of paper, and by bringing the overlapping end to its original position a tracing with a pencil will show the outline of the body in the plane of examination. The skin mark positions are then transferred to the diagram and we have an approximate duplicate of the shape of the body and the locations of the external skin markings.

If, on this diagram, Fig. 110, one numbers the skin marks in series, 1, 2, 3, 4, 5. and 6, and joins 1 and 4, 2 and 5, and 3 and 6, and if the work has been strictly accurate, that is, if the sight lines were properly established, and if the shape of the body did not change by change of position when the band was put on, supposing the band has been properly formed and not distorted afterwards, these three lines will intersect in a point; practically they

are likely to form a small triangle, but with an excellent chance of the projectile being located in this small area. If one now identifies the diagram, so formed, with a cross section anatomy for the same region of the body, definite anatomical information as to the position of the projectile and the relative position of muscles or organs likely to be encountered in its removal is gained.

It is also possible to use two short bands at right angles

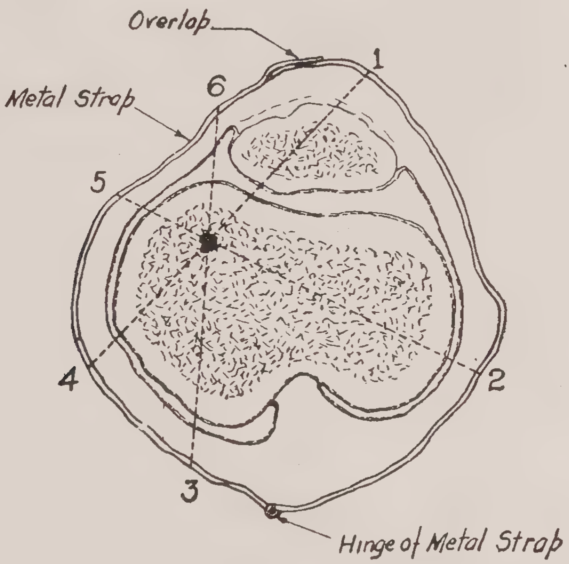


FIG. 110. Principle of profondometer strip.

to each other, that may be made to conform to the body at a desired point, and to mount an indicating rod for use during operation.

The value of this method will depend to a considerable extent upon the care exercised in forming and handling the strip and in properly adjusting it to the cross section anatomy. It is suggested that in many cases at least one of the skin marks might well have definite relation to some anatomical landmark, so that there could be little opportunity for a rotation of the band with reference to the anatomical chart. This will be especially true of portions

where the cross section is nearly a circle. It should also be observed that the accuracy of this method increases when the three sight lines are made to differ materially in direction. In some cases this would be a difficult matter, as in the case of a seriously wounded patient, or one for whom change of position on the x-ray table is painful.

It is advised in every case that three lines of sight be determined, marking six skin points, and for this purpose the parallax localizer furnished in the army outfit will be found very valuable, as it permits of marking the skin on the under side with the same degree of certainty as on top. It may be noted also that the method here described eliminates the necessity of using more than one distinctive skin mark, and it would do no harm, when using this method with a parallax localizer as a marking device, if at least one depth were determined as a check upon the accuracy of adjustment of the profondometer band.

Those who are especially interested will find articles by Major Flint giving more details with reference to this method in *The Military Surgeon* of March, 1917, and the *Annals of Surgery* for August, 1917.

Specific Instructions for Method D.—It would be rather difficult to give definite directions for the use of the profondometer, because no explicit measurements are made by the roentgenologist. It will, perhaps, suffice to point out wherein difficulties or inaccuracies are likely to result.

1. It should be mentioned that the six points representing the entrance and emergence points of the x-ray beams used, should, if possible, be well spaced round the body; in other words the angles between the diametral lines should be as large as possible.

2. Great care must be taken in the matter of forming the metallic strip to fit the body in the plane of the skin marks and to insure that it is removed without distortion. If time

permits it might be wise to check by a second attempt.

3. Care should be taken to properly orient the diagram secured in this way with the cross section anatomy chart and, to facilitate this, it might be well to identify one of the skin points with reference to the immediately underlying anatomy.

Method E.—There have been devised both before and during the war a very considerable number of mechanical indicators or compasses to be used during the operation as a surgical guide to better utilize information acquired by the x-ray examination. Of these, the one devised by Dr. Hirtz of the French Roentgenological Service has been most generally approved by roentgenologists and surgeons.

As originally proposed, this instrument was intended to be used in connection with radiographic work, whereby a permanent record could be made for the later setting of the compass, provided the identifying skin marks were not obliterated. On account of the very considerable time necessary to prepare a negative for examination and measurement, it has been found desirable in many cases to operate the compass by data secured from fluoroscopic examination, which is much more expeditious and, in many cases, will serve fully as well.

The essential feature of the Hirtz compass is the possibility of adjustment of the movable legs that support the instrument, so that when resting on fixed marks on the body of the patient the foreign body will be at the center of a sphere, a meridian arc of which is carried by the compass. This arc is capable of adjustment in any position about a central axis. An indicating rod passes through a slider attached to the movable arc in such a way as to coincide in all positions with a radius of the sphere, and whether it actually reaches the center or not it is always directed toward that point. If its movement to the center

of the sphere is obstructed by the body of the patient, the amount it lacks of reaching the center will be the depth of the projectile in the direction indicated by the pointer.

The value of the compass lies in its wide possibility as a surgical guide, in that it does not confine the attention

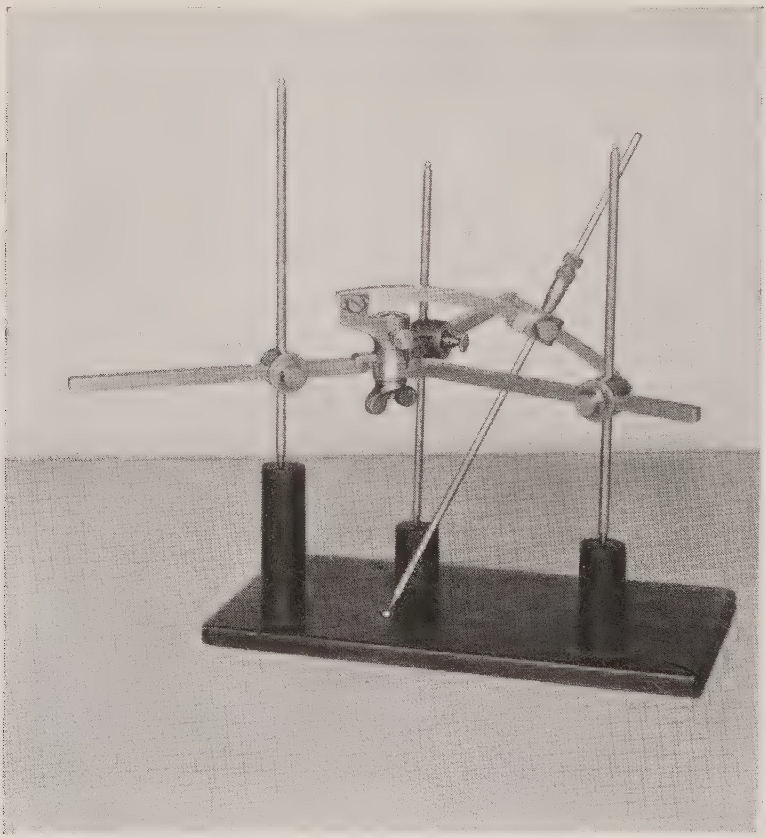


FIG. 111. Hirtz compass.

of the surgeon to a single point marked on the skin, with a possible uncertainty as to the direction in which he should proceed in order to reach the projectile, but gives him a wide latitude of approach and explicit information as to depth in a direction of his own selection.

The compass is shown in Fig. 111 and schematically in Fig. 112. Three metal arms respectively labeled 1, 2, and 3 in clockwise rotation are so mounted as to turn freely

upon a central pivot and have their upper surfaces all in a single plane. Each of these arms carries a slider, which may be adjusted to any position along the length of the arm. Each slider has an adjustable leg at right angles to the plane of the arms, that may be held in any position by a small thumb screw. These legs are graduated and the zero point is not at either end of the legs, but a few centimeters below the upper portion, which terminates in a small knob. The center post about which the arms ro-

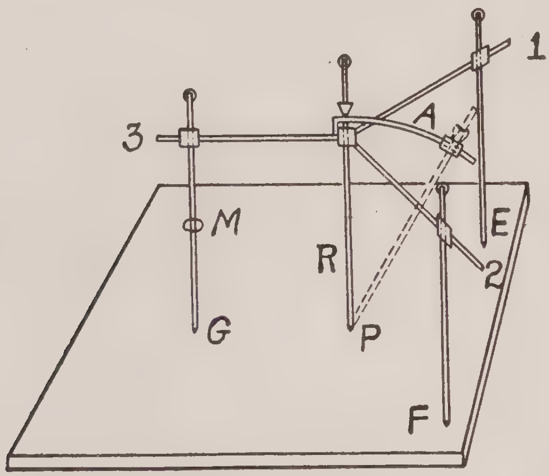


FIG. 112. Schematic drawing of Hirtz compass with legs adjusted at zero points and resting on a plane.

tate has a hole at right angles to the plane of the arms and is also shaped to carry the curved metal arc, *A* (Fig. 112). The hole in the slider on arc, *A*, carrying the indicating rod, can be made to coincide with the opening through the center post.

When the three legs are set at zero, quite irrespective of the position of the slider on the arms or of their angular position, and the compass stands on a plane surface, the indicating rod, passed through the slider on arc, *A*, will touch the supporting plane at the center of the sphere of which *A* is a meridian arc. A friction clip on the indicating rod may be adjusted in contact with the slider on *A*,

and the distance from the lower end of this clip to the pointed end of the indicator will be the radius of the sphere of which *A* is an arc.

Fig. 113 shows the compass with the legs shifted so that they no longer stand on the base plane, and, in fact, are at quite different heights; but the arc, *A*, and the arms of the compass have *not been displaced,* so that the pointer still reaches the center point, *P*, in this plane.

Fig. 114 shows the compass actually set upon the body of

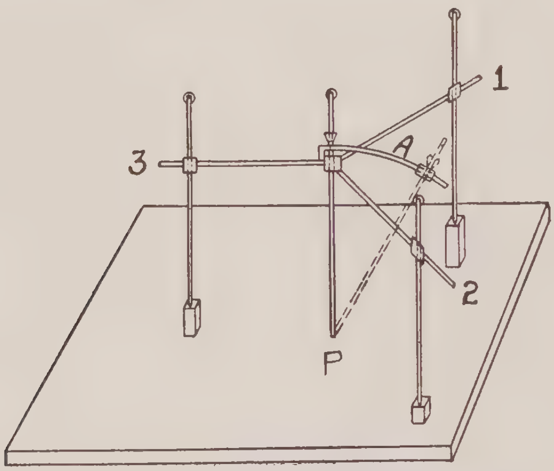


Fig. 113. Arms and indicator of Hirtz compass. Same position as in Fig. 112, but with legs elevated on blocks whose tops might correspond to skin markers.

a patient, its legs resting on three skin marks, *M*, *N*, and *O*, and with the indicating rod pointing toward the projectile, but failing to reach it because of contact with the skin of the patient at *S*. The depth of the projectile in this particular direction is indicated in Fig. 114 by *d*. If, now, the indicating rod is placed in the slider carried by the arc, *A*, the rod touches the skin at a different point, *S′*, and the distance between the friction clamp on the rod and the upper surface of the slider on the arc, *A*, will be the depth of the foreign body along the direction indicated by the dotted line. It is evident from the construc-

tion that the surgeon may place the arc, A, in any position throughout 360°, and the slider at any position from the center to the extreme end of the arc, and still have the indicating rod point to the foreign body and show its depth from the point of contact with the skin. Fig. 115 shows the compass in position on the patient at operation.

The exact amount which each leg of the compass must be shifted from its zero point in order to stand on the marker

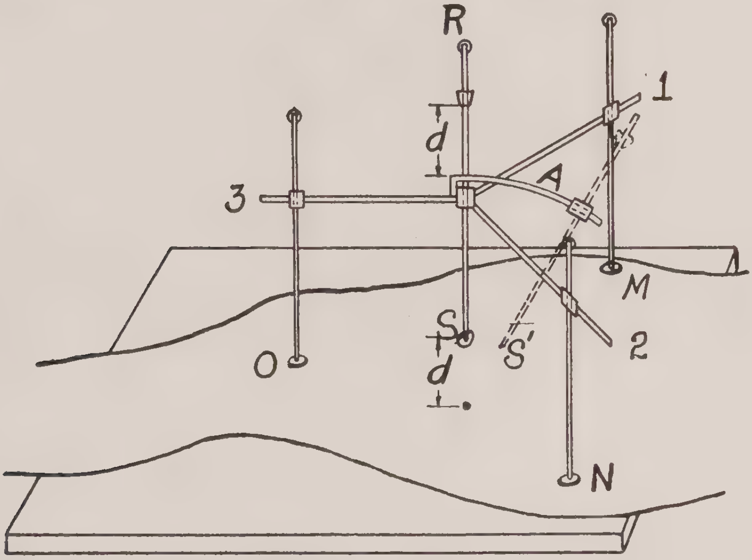


FIG. 114. Schematic drawing of Hirtz compass set up on skin of patient.

to which it belongs and yet have the indicating rod in the proper position is easiest seen in Fig. 116, in which only a single leg of the compass is shown; but the same will apply to each of the legs in turn. Imagine a plane, parallel to the plane of the three arms of the compass, to be drawn through the projectile. The leg attached at arm number one, standing on the marker, M, would, if it could pass down to this plane, intersect the plane at the point, E, and, under these circumstances, the indicator passing through the central post of the instrument would touch the skin at S, vertically above P. If the distance from the

plane, from which measurements are made, to the lower plane, containing the projectile, is measured and, likewise, the distance MM', it is seen that the amount by which this particular leg is raised from its zero point, where it would be set if it reached the point, E, will be the difference between the depth of the foreign body and

FIG. 115. Hirtz compass in position.

the depth of the marker from *any plane of measurement*, for example, that of the fluoroscopic screen or a photographic plate. The fluoroscopic screen may be placed in any position parallel to the base plane, EP, and the difference, ME, would be quite independent of the height of the plane from which *all measurements* are made.

This may be summarized by saying that each rod is to be shifted from its zero point an amount equal to the *difference* between the depth of the projectile below the flu-

oroscopic screen, or other plane of reference, and the depth of the skin mark upon which this particular leg would stand, measured from the same plane. It is absolutely essential in the use of the compass to adopt a systematic procedure, so that the arm to carry the leg is identified with the depth measurement of its own skin point.

The data necessary to properly adjust the compass may now be stated by reference to Figs. 112 and 116. The indicating rod in the central position and the three legs

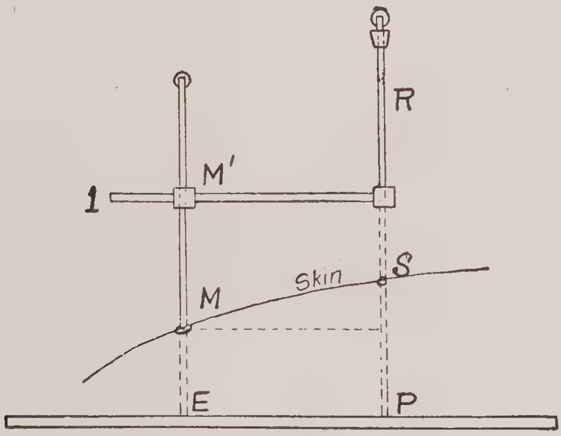


FIG. 116. Reason for shift of leg of compass from zero point by the amount stated.

of the compass mark out, in any plane parallel to the base plane of Fig. 112, four points of definite position in the plane. Any vertical shift of the legs will still allow them to retain their position in lines passing through the points, *E, F, G* and *P*. The point *G*, Fig. 112, is then in a vertical line passing through the marker, *M*, and the data necessary to set the compass must give the position in a plane of these four points and, in addition to this, must give the depth from a fixed plane, parallel to the base plane, *EFG*, of the three markers on the skin of the patient and of the projectile within the patient's body. Whether this data is to be found by a photographic or a fluoroscopic

process is immaterial, as the steps in its use will be identical.

When a fluoroscopic method is to be used, an auxiliary device may be found of considerable aid in rapidly and accurately securing the requisite data. Such a device is

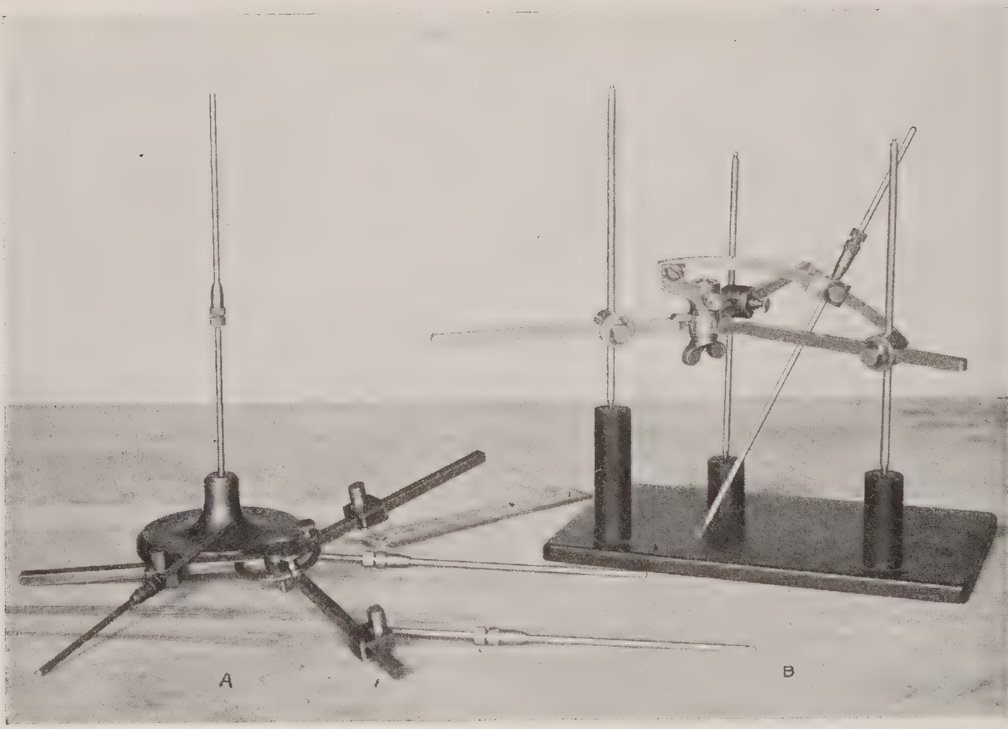


FIG. 117. Accessory apparatus for fluoroscopic work with Hirtz compass.

(a) Auxiliary compass, pedestal support and three markers with friction clips.

(b) Hirtz compass mounted with the three legs at different levels, so that a pointer reaches white spot on the base plane at the center of the sphere of which the curved arc is a part.

shown at *A*, Fig. 117, and consists of three arms, each with a slider very similar to the original compass. In fact the latter may be used with rather less convenience, by removing arc, *A*, and allowing the indicating rod to project a short distance below the center, with the legs temporarily removed. The auxiliary compass has its arms num-

bered in the same way as the original Hirtz compass and has a projecting pin which fits the perforation in the screen. One of the arms is rigidly attached to a ring concentric with the axis of rotation about the pin, while the other two are movable, but may be clamped by thumb nuts to the ring. It is evident that placing the perforation in the screen in the vertical ray passing through the projectile definitely fixes the position of the center post. If, then, each marker in turn is brought into the vertical ray and the arm and slider adjusted so that the hole in the slider matches such a projection of each marker, the three openings in the sliders and the central pin fix the four points which it is necessary to obtain. It then remains to determine the depth of the projectile, for which one of the methods, *A*, *B*, or *C* should be employed and also to determine the distance from the screen to the opaque markers. When using the fluoroscopic method, the latter depth can be very readily determined by simply passing a suitable measuring rod through the perforated screen, which has been brought into the vertical ray passing through the marker. This depth is to be recorded and accurately identified with the arm carrying the slider corresponding to that particular skin marker. In order to facilitate this measurement a set of three measuring rods with friction clips, differing slightly in shape, are provided. As soon as these four depths and the four marks in the plane of the screen have been determined, the work of the roentgenologist is completed, provided he has made sure that the skin marks are plainly visible. The adjustment of the compass may then be carried out by an assistant to either the roentgenologist or the surgeon, after which the instrument can be sterilized and is ready for the surgeon's use.

Fluoroscopic Method With Auxiliary Compass—

1. Find the shadow of the projectile, P_0, on the screen, and reduce the size of the diaphragm, keeping the shadow in the center of the illuminated area.

2. Adjust the screen so that the opening at the center of the screen coincides with the center of the shadow; lock screen carriage in this position for all except vertical travel.

3. Mark the skin through the opening by use of the special marker provided.

4. Determine the depth of the projectile by either *Method A* or *C*.

5. Raise the screen and attach three metallic markers (preferably three small washers) to the skin at suitable points, and *mark the skin* at each point selected. Choose skin points with care to ensure:

   a. No interference with probable incision.
   b. Proper stability of the compass.
   c. As firm foot points as possible.

6. Lower the screen near to or touching the skin, with the central hole still in the vertical ray through the projectile, and insert the pin of the auxiliary compass in the hole. Be sure that the screen is locked in position. Bring arm marked 1 to point toward the operator's right and loosen thumb nuts on arms 2 and 3.

7. Shift the tube to bring the right-hand marker in the vertical ray (leaving screen locked), and adjust the slider on arm number one so that its opening coincides with the projection of the marker, Fig. 118. If washers are used the round opening is easily identified.

8. Do the same with each of the other two markers, ensuring that number (1) does not move when adjusting the others (a small clamp will aid in this) and lock each

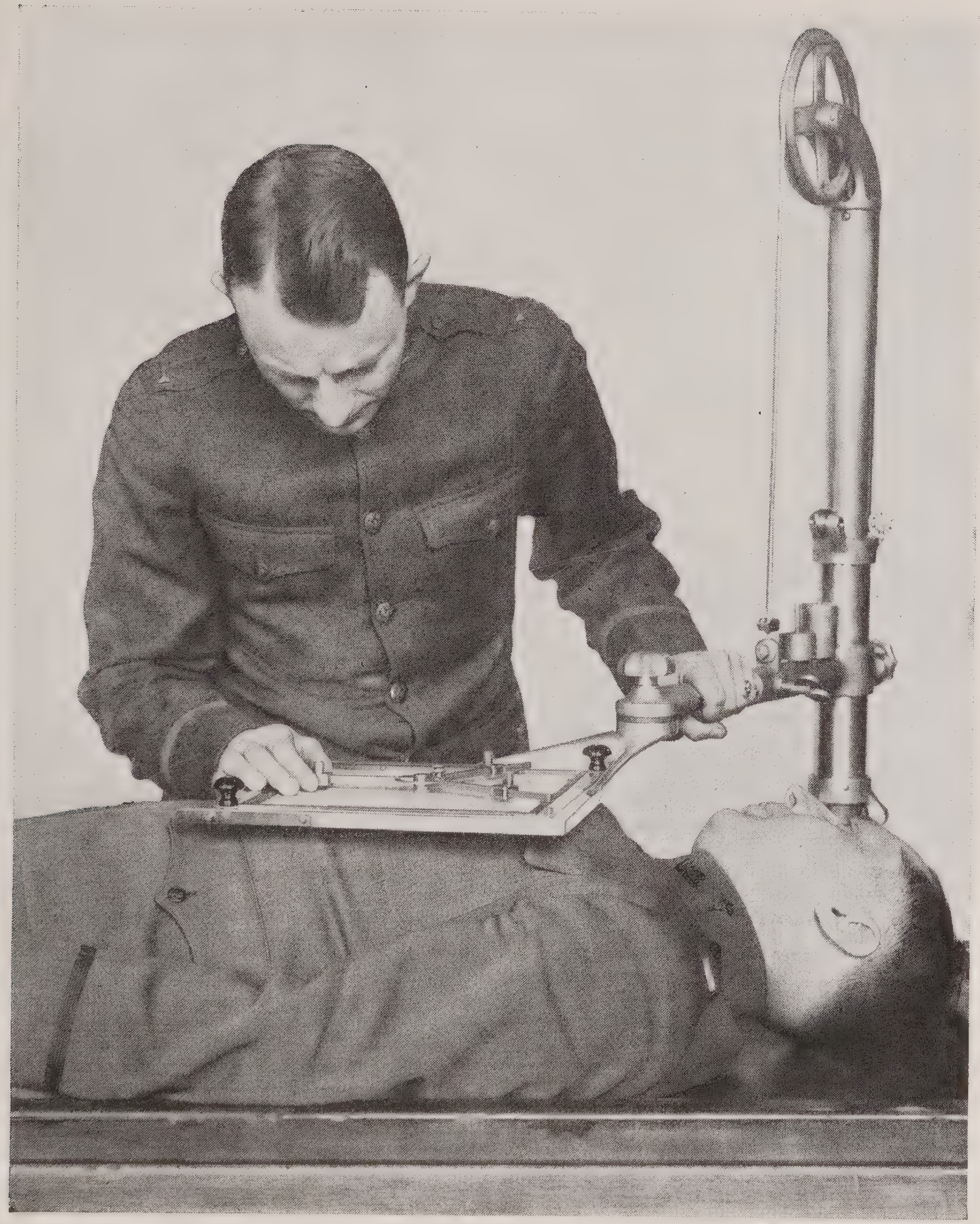


FIG. 118. Method of using fluoroscopic adapter with Hirtz compass.

arm. The central pin and the three sliders then give the positions for the arms and sliders of the compass.

9. Remove the auxiliary compass and determine the

depth of *M*, *N*, and *O* below the upper surface of the glass on the screen. For the depths of *M*, *N*, and *O* use the small rods provided with friction sliders and make the measurement by passing the rod through the perforation in the screen, which, for this purpose, is to be brought vertically over each marker in turn. If the friction clips are then pushed down until they touch the glass and are properly adjusted as to friction, the distance from the clips to the end of the rod will indicate the depth desired. These sliding clips are shaped to correspond to the projecting blocks on the sliders of the auxiliary compass, and care must be taken to use them in their proper places, so that there is a complete identification of the compass slider and the depth of the marker corresponding. Form the habit of using these in a definite order, during these depth measurements, to minimize chances of error. If no further fluoroscopic work is to be done these depths may be determined in daylight. Otherwise use the vertical ray from the tube.

Setting the Hirtz Compass—

A. By Use of the Auxiliary Compass—

1. Remove the arc and the indicator rod; lower the three legs until the upper (rounded) ends project one to two centimeters.

2. Lay the auxiliary compass on a flat surface with the center pin upward. Invert the Hirtz compass and place the central hole on the pin of the auxiliary. Unlock wing-nut at center of compass, thus releasing the arms; bring arm number 1 and its slider to such a position that on loosening leg number 1, it will drop into hole of the number 1 slider of the auxiliary. Tighten set screws of slider and of leg number 1. Fig. 119. Proceed in the same manner with arms, sliders and legs numbers 2 and 3. Tighten wing-nut at center of Hirtz compass, thus locking compass arms.

3. If pedestal support is provided, set the lock sleeve on the vertical rod, so that, when the pedestal stands on a flat surface, and the Hirtz compass is placed thereon.

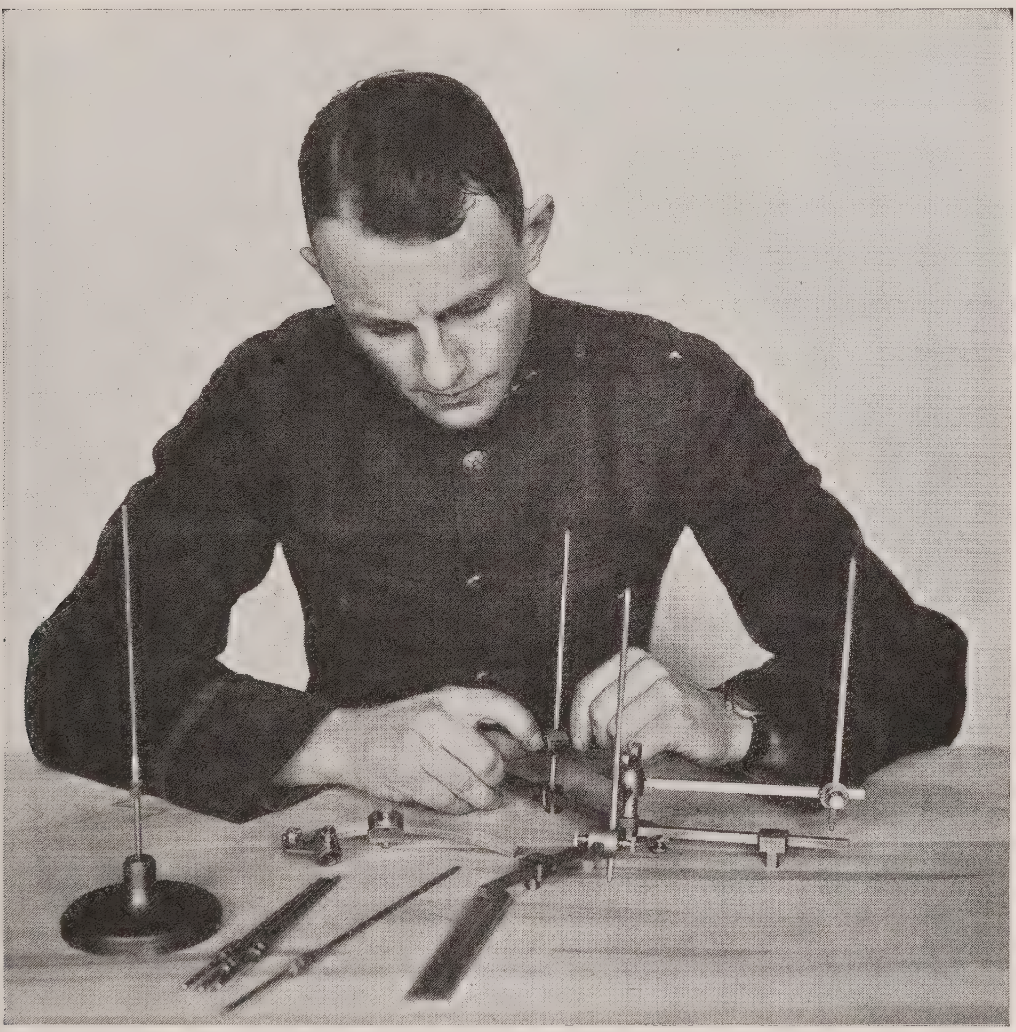


FIG. 119. Setting arms and legs of Hirtz compass directly from the auxiliary compass.

with the pedestal rod through the central hole of the compass, it will be supported in such a position that the legs will drop to their zero points when loosened, leaving the compass supported on the pedestal.

4. Shift each leg an amount equal to the difference be-

tween the depth of the projectile and the depth of the skin marker on which each individual leg is to stand. (Leg number 1 stands on skin marker number 1, etc.) Tighten each leg, replace compass arc and indicating rod, the latter with lock sleeve properly set, and the compass is ready for sterilization and use by the surgeon.

NOTE.—This subtraction can conveniently be made by laying off on paper the distance from the top of the lead glass on the screen to P, then, placing auxiliary rod number 1 with its sleeve indicating the skin depth for marker one, mark this distance on the line previously made, and reset the sleeve to the length remaining on the projectile depth line.

It is recommended that even if the compass is to be immediately set direct from the auxiliary a record of the data necessary for setting be made and retained until after the operation.

B. From the Diagram of Data—

1. The auxiliary, having been set to mark shadows on the screen, is placed on a plain sheet of paper with center pin down. Indicate with a pen the spot on the paper where the pin touches and mark it P_0 (being directly over the projectile)—a small drawing board with a hole in the center, in which the pin may be inserted through the record paper, may be helpful. Indicate the locations of the holes in sliders 1, 2, and 3, thus giving their relations to P_0; identify each by number and write opposite each the depth in centimeters to the skin below the fluoroscopic screen. The depth of P_0 below screen must be similarly indicated.

2. Take the Hirtz compass with indicating rod inserted in central hole, and set point of indicating rod on P_0 of diagram. Loosen wing-nut at compass center, thus releasing arms; bring leg number 1 to stand on mark number 1 of diagram. Proceed identically with legs numbers 2 and

3; then, with indicating rod and the three legs accurately on the proper points of diagram, tighten wing-nut to lock compass. Tighten all set screws.

3. Place the compass on pedestal support and proceed as indicated in paragraph 4 above.

The instrument is now ready for sterilization and use by the surgeon. Care must be taken to avoid handling the compass in any manner that would displace any of the settings. In case of deferred operation, the four skin marks should be tattooed, or they must be renewed with sufficient frequency to insure their identification at time of operation. If metal washers are used, they may be

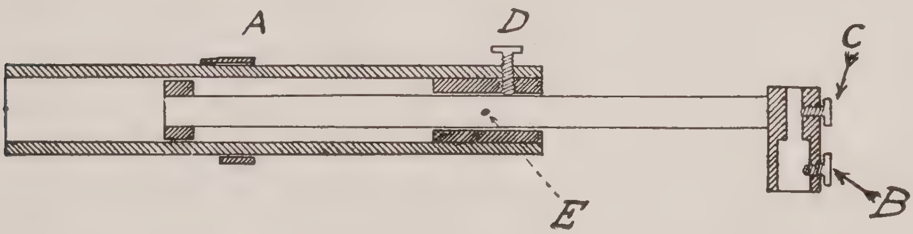


FIG. 120. Detail of holder for direct setting of Hirtz compass.

sterilized and attached at the time of the operation; they serve very well to hold the compass legs on their proper skin points.

Direct Setting of the Hirtz Compass.—Several devices for holding the Hirtz compass in order to make a direct adjustment of the foot points and leg heights on the patient have been proposed. This method possesses two distinct advantages: (1) it may be done quite expeditiously; (2) it indicates clearly to the operator how the compass is going to stand on the patient when in use. Its disadvantages are: (1) the necessity of considerable illumination in the fluoroscopic room when placing the compass; (2) danger of movement of the patient between localization and final adjustment; (3) need for the compass both in the fluoroscopic room and in the operating room.

In order to adapt this method to the standard table, the design shown in Fig. 120 has been developed. This consists of a tube fitting into the socket of the screen carrier, holding a square sliding rod with an end socket taking the hub of the compass.

The collar, *A*, on the tube has a V-shaped projection intended to fit a notch in the carrier socket so as to prevent rotation from a definitely determined position.

The fundamental principles in this method are the alignment of the central axis of the compass with the vertical ray through the projectile, and the bringing of the compass to the proper height so that the top of the slider on the arc, when in its central position, is at a distance from the projectile equal to the *radius* of the arc.

In order to secure the former, the holder should enable us to readily make the plane of the arms level. Then, the compass should be allowed to move up or down in a vertical direction without rotation. When the indicator is placed in the central position and the compass is properly placed on the patient, the radius mark on the pointer will be as far above the arc slider, through which the pointer is inserted, as the measured depth of the projectile along the vertical ray. While rigidly held in this position the arms and legs may be adjusted at will to support the compass in this position, Fig. 121.

Care must be taken to ensure:

1. That the patient does not move between the localization and the completion of the adjustment.

2. That the pointer is raised from its zero the correct distance.

3. That all parts of the compass are *locked* before removal from the body.

The holder must be adjusted before it is used the first time as follows:

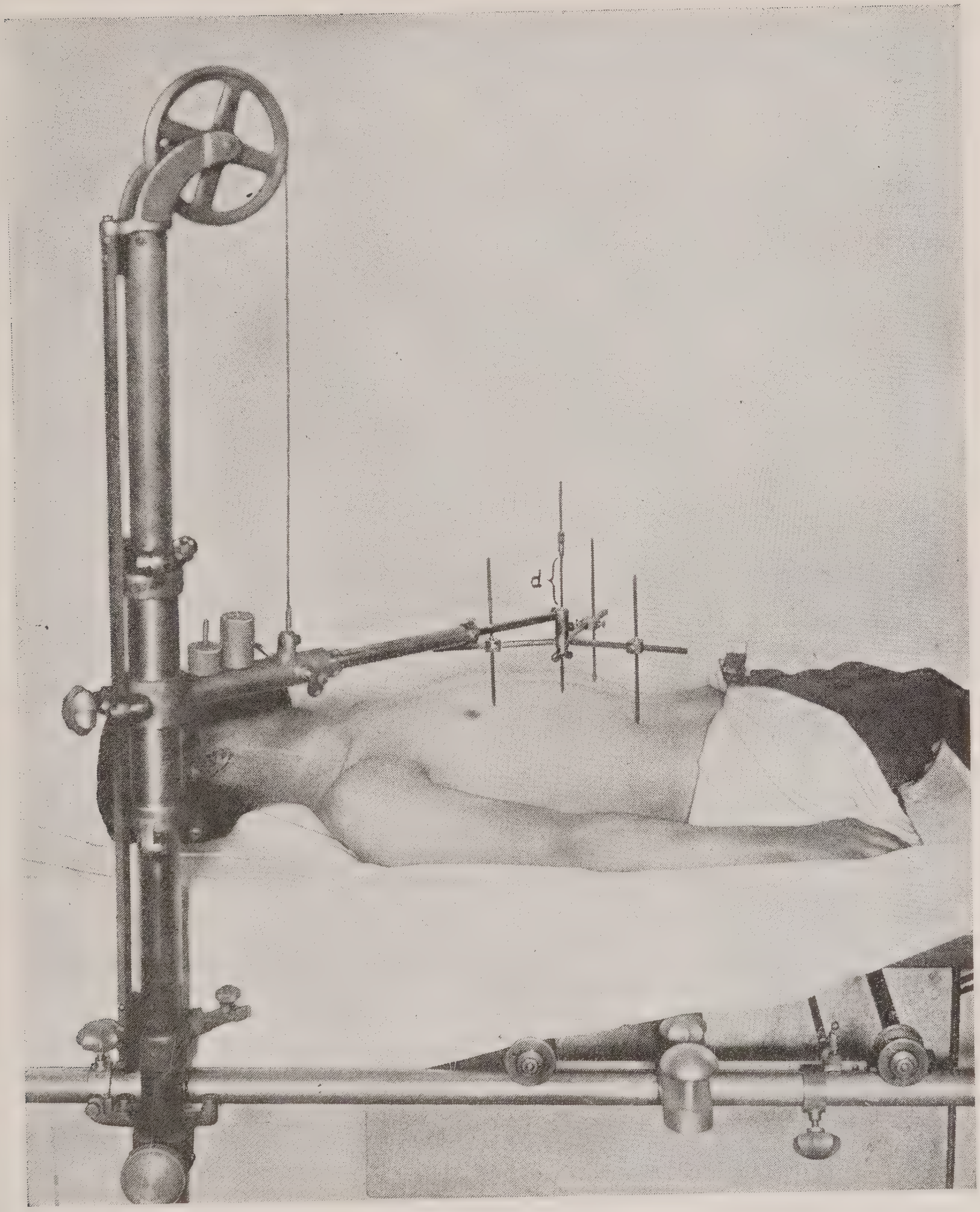


FIG. 121. Direct setting of Hirtz compass. Compass and holder in position.

1. Remove screen-holding rod from the horizontal socket and insert holder.

2. Remove arc from the compass, insert hub in the

holder, and place two of the arms close together so that the line of the holder bisects the angle between them. Then lock the center arm clamp.

3. Place a small level on the two arms perpendicular to the holder rod, and rotate rod until this shows level, then clamp by socket set-screws.

4. Make a scratch mark where the "V" on the ring comes in contact with the socket.

5. Remove the holder and file a small notch with a triangular file to take the "V" on the collar.

6. Test out as to level, when the holder is replaced in the socket with the "V" engaging the notch. If not quite correct, loosen the set screws at the end where the square rod enters, rotate to level, and fasten firmly.

The above needs to be done only once and the procedure for use is then quite simple.

1. Remove arc from the compass and insert in the holder, fastening with the thumb nut, *B*.

2. Set the sliding clamp on the indicator rod at the ring mark, i. e., so that the distance from the lower end of the slider to the pointed end of the indicator is the radius of the arc.

3. Insert indicator in the compass holder and raise until the distance from the top of the brass holder to the lower end of the sliding clamp is the projectile depth below the skin mark. Fasten by nut, *C*.

4. Raise the legs of the compass and adjust the holder until the lower end of the pointer rests on the skin mark. Lock carrier in position.

5. Place arms and feet as desired so that the latter rest on as firm skin points as possible, and *clamp all parts* of the compass.

6. Raise compass *slightly* by the vertical movement of the carrier, mark skin points for the feet, and identify them

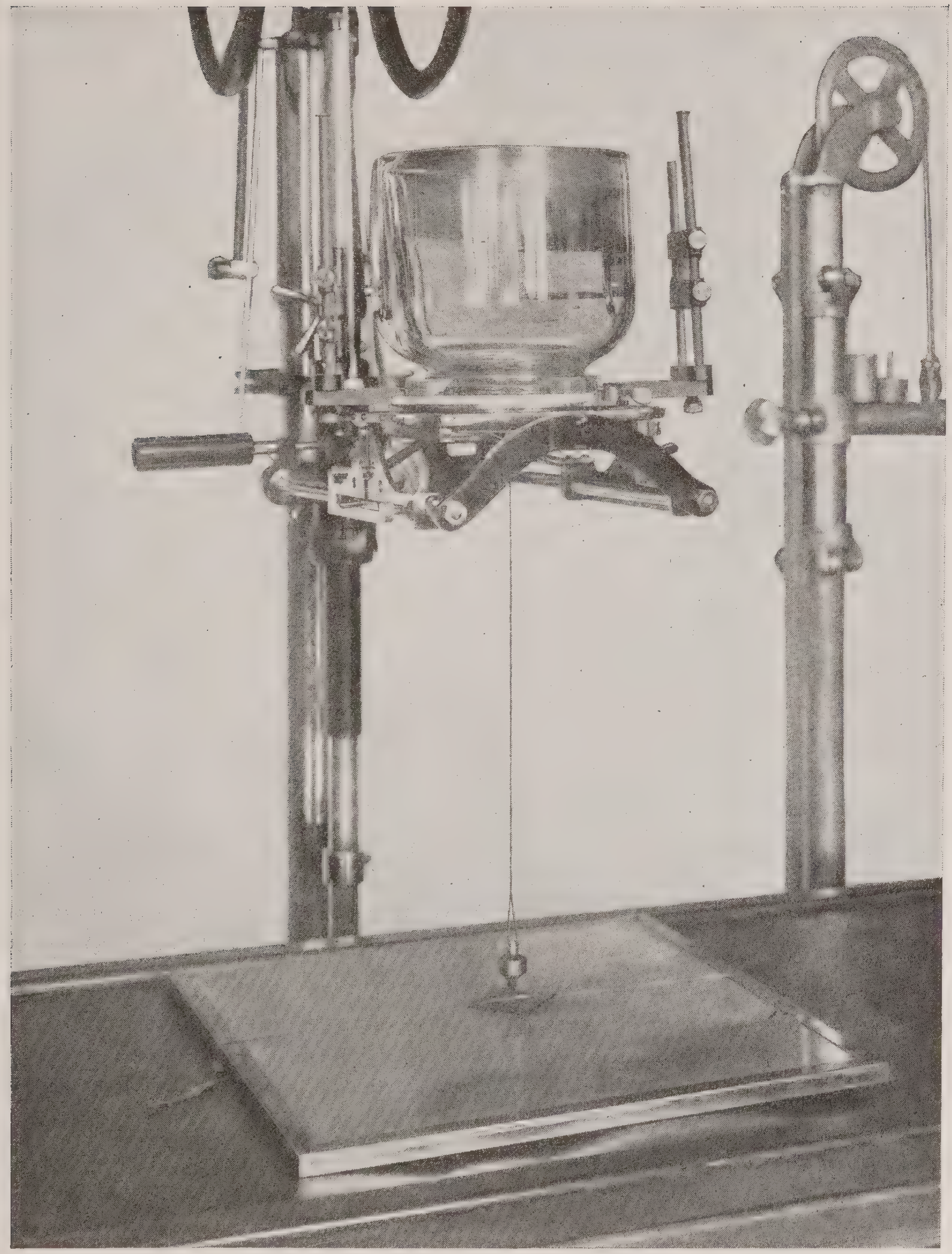


FIG. 122. Centering of tube above plate holder on cassette with small cross wires, photographic method, Hirtz compass.

clearly. This method is much more convenient than to mark the skin first and then adjust the compass to fit the marks.

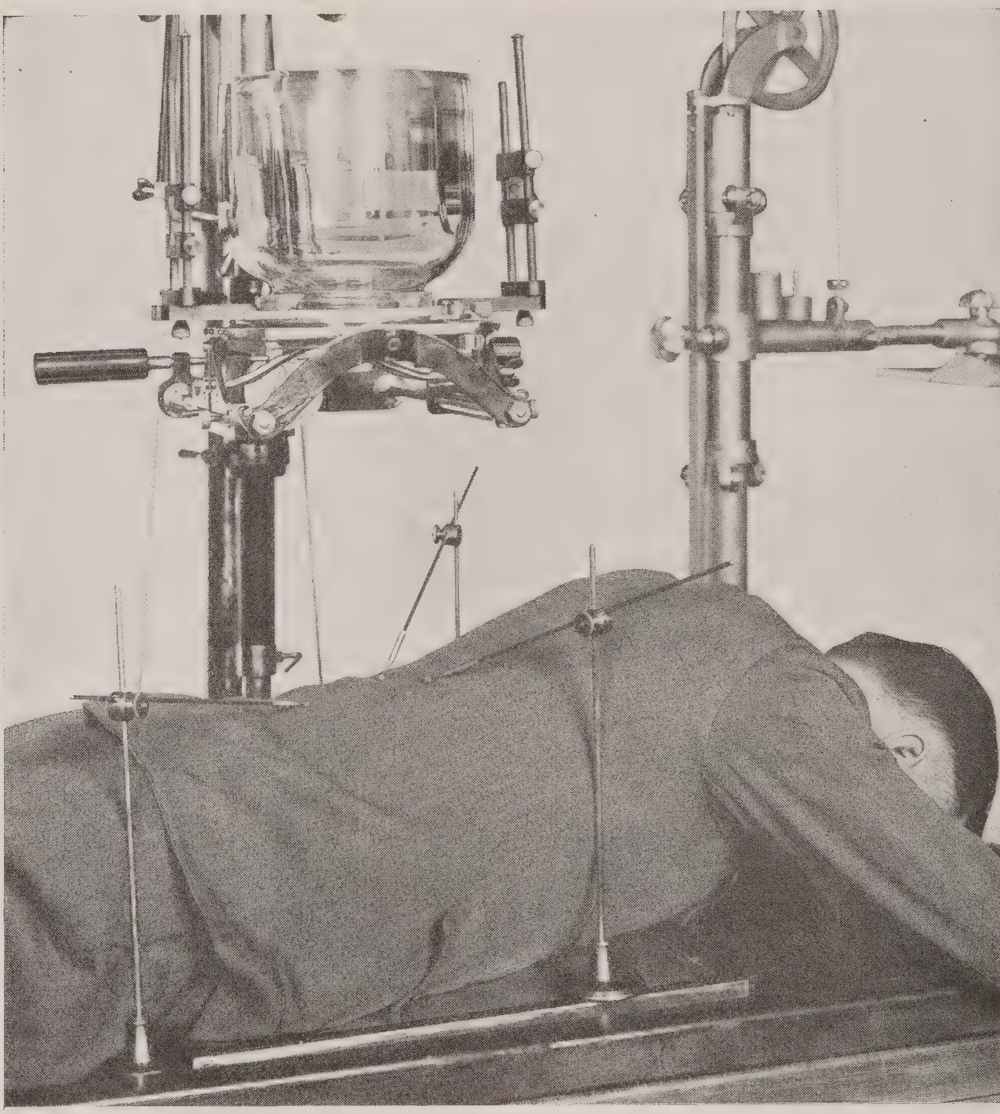


FIG. 123. Skin markers, plate holder and tube holder in position for photographic method, Hirtz compass.

7. Remove compass, read and record height settings of legs, then record position of foot points, and center for resetting the compass later if it should be necessary.

8. For use in the operating room the compass may be sterilized by a flame.

Use of the Hirtz Compass with Plates.—When it is desired to establish the data necessary for the use of the compass with photographic plates or films, it is necessary that two exposures be made from two different target positions, either upon a single plate, or upon two separate plates or films, without movement of the patient or skin markers. The latter method is usually preferred.

There is furnished for this work a small, flat square of celluloid into which are inserted two small steel wires forming a right-angled cross. The celluloid has two holes punched in diagonally opposite corners, through which a tape may be passed, and this is to be tied around the tunnel plate changer so as to fix the desired centering mark, when two plates or two films are to be used.

Fig. 122 shows how the tube is centered, using a plumb line to secure exact position. This must be done before the patient is placed in position; and care must be taken not to disturb the adjustment.

Fig. 123 shows the tube, patient, and markers in position for one of these exposures. Do not forget to attach to the plate tunnel the marking device or to use the three metallic markers in contact with the patient's skin at points properly chosen and marked for identification.

The principle of the method is shown in Fig. 124. A small marker, X, is placed approximately at the center of the plate, if one plate is to be used, or on top of the plate changing tunnel, if two plates are to be exposed. Let CX be a perpendicular erected to the plane of the plate at the point X and extending upward a distance of 60 centimeters. Let F_1 F_2 be positions of the focus in a line parallel to the plane of the plate at the level C, and assume that CF_1 and CF_2 are each three centimeters in length. Sup-

pose that M is one of the markers on the patient's body. When an exposure is made with the target at F_1, the shadow of M will fall on the plate at M_1 and, when an exposure is made from the position F_2, the corresponding shadow will be M_2. Had the exposure been continuous during the motion of the target from F_1 to F_2, there would have been found on the plate a straight line of shad-

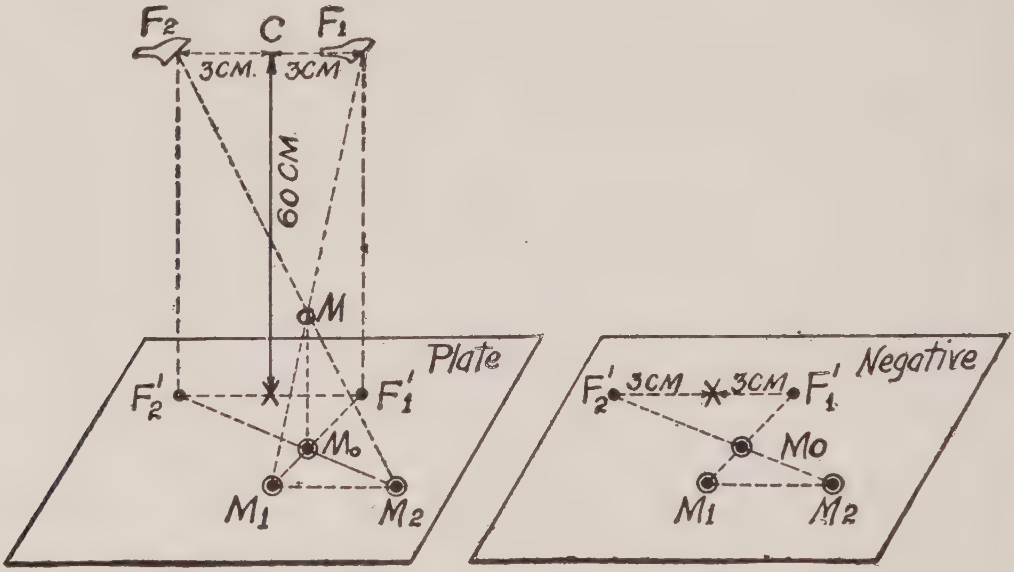


FIG. 124. Schematic representation of plate, cross wire marker and tube focus positions for radiographic use of Hirtz compass.

FIG. 125. Construction for finding one of the foot points M from the shadows of a corresponding marker as shown at M_1 and M_2 and the shadow of the cross marker, X.

ows connecting M_1 and M_2. If we drop perpendiculars from the two focal positions to the plane of the plate, intersecting it at the points F'_1 F'_2, we see that F'_1 F_1 M_1 is a plane perpendicular to the plate and passes through M_1, and the trace of this plane upon the plate is F'_1 M_1.

In the same way a plane passed through F_2 F'_2 M_2 will be perpendicular to the plate and its trace will be F'_2 M_2. It follows from geometry that the intersecting line of these two planes, MM_0, will be a line passing through the point

M and perpendicular to the plate. Consequently M_0 is the foot point of this marker on the plate to be used in the compass adjustment. Also the lines M_1 M_2, F'_1 F'_2 and F_1 F_2 are parallel.

Fig. 125 shows part of a developed negative upon which there appears a shadow at M_1, a shadow at M_2 and a single image of the marker on the plate—a single image, since its motion is zero or nearly so, the marker being almost in contact with the plate itself. If one joins M_1 and M_2 by a straight line and then draws through the center of the cross a line parallel to M_1 M_2 and measures a three centimeter length on this line through X in each direction from the center of the cross, the points so determined will be F'_1 and F'_2 of Fig. 124. Cross connection between the ends of these lines, that is F'_2 M_2 and F'_1 M_1 then definitely locates the point M which will be the foot point sought.

The length of the line M_1 M_2 will clearly decrease as M is placed nearer the plate, and increase as it is raised. For the definite 60 centimeter target-plate distance and 6 centimeter tube shift there corresponds one height MM_0 for one image shift M_1 M_2. These relative values are shown in Table I in which all measurements are given in centimeters or tenths of centimeters.

Fig. 126 shows a full construction and necessary record derived from the photographic plate used in setting the compass. This data is used exactly as was that derived from fluoroscopic examination.

It will require a considerable amount of skill and judgment to so place the markers on the patient's skin as to give reliable readings and at the same time furnish proper support for the compass when used at operation. Especially one must insure that the shadows of all the markers fall on the photographic plate. It is also clearly undesir-

able to have the lines whose crossings are to indicate foot points for the compass setting too nearly parallel, as in that case a slight error in their location may bring a decidedly large shift in the position of foot points. Transparent celluloid scales are sometimes furnished, which assist somewhat in determining whether the shadow of the markers will fall on the plate.

Operation—

1. Knowing approximately, by previous fluoroscopic or other examination, the position of the projectile whose localization is sought, select a plate changer of proper size, attach the cross, and place on the table in the position in which it is to be used.

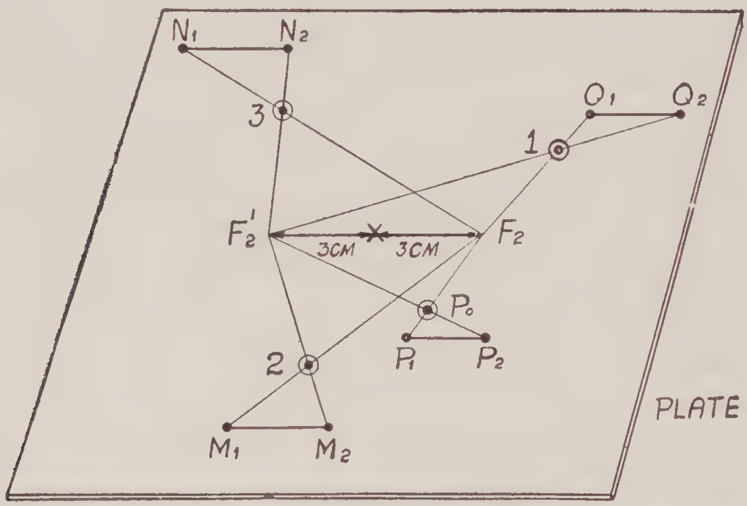


FIG. 126. Complete chart for setting feet of Hirtz compass.

2. By means of the plumb bob furnished, adjust the tube stand so that the central position of the target shall be vertically over the metallic cross, and be sure that the distance CX, Fig. 124, is 60 cm. Adjust stops to allow the tube to move 3 cm. in each direction from the central point.

3. Place the patient on the tunnel plate changer, taking

care that the cross, plate changer, and tube are not displaced in the process. Or, if the tube holder is rotated, fix stop for its exact return.

4. Make sure that the tube is three centimeters from its center point and insert a plate.

5. Place the three skin markers in the desired position. The balls as furnished with the apparatus may be used, or small metallic markers, preferably V-shaped, may be attached to the patient's skin with small pieces of adhesive.

6. Make the exposure needed.

7. Remove the first plate, shift the tube and make the second exposure. Do not attempt to get the data from the plate or film until it is dry. If it is once scratched or smeared, it will be impossible later to get good measurement.

If the exposures are to be made on a single plate, be sure not to overexpose. When using two plates, the image of the cross is used to superimpose the plates and to transfer the data to the record sheet.

8. Make the record described above, locating the foot points and the center points.

9. Read M_1 M_2, N_1 N_2, O_1 O_2 and P_1 P_2 in centimeters and fractions, enter these on the record under column marked *spread*, and enter under *height* the corresponding number in the table on page 266.

Thus:

	Spread	Height	Shift	
M_1 M_2	1.5	12.	6.6	P_1 P_2—M_1 M_2
N_1 N_2	2.1	15.5	3.1	P_1 P_2—N_1 N_2
O_1 O_2	3.6	22.5	—3.9	P_1 P_2—O_1 O_2
P_1 P_2	2.7	18.6		

The equipment supplied for use in *Method E* is shown in Fig. 127.

TABLE

Focus Plate Distance 60
Tube Shift 6

Spreading	Height	Spreading	Height	Spreading	Height
.1	1.0	1.75	13.55	3.4	21.7
.15	1.45	1.8	13.85	3.45	21.9
.2	1.95	1.85	14.15	3.5	22.1
.25	2.4	1.9	14.45	3.55	22.3
.3	2.85	1.95	14.7	3.6	22.5
.35	3.3	2.0	15.0	3.65	22.7
.4	3.75	2.05	15.3	3.7	22.9
.45	4.2	2.1	15.55	3.75	23.05
.5	4.6	2.15	15.85	3.8	23.25
.55	5.05	2.2	16.1	3.85	23.45
.6	5.45	2.25	16.35	3.9	23.65
.65	5.85	2.3	16.65	3.95	23.8
.7	6.25	2.35	16.9	4.0	24.0
.75	6.65	2.4	17.15	4.05	24.2
.8	7.05	2.45	17.4	4.1	24.35
.85	7.45	2.5	17.65	4.15	24.55
.9	7.85	2.55	17.9	4.2	24.7
.95	8.2	2.6	18.15	4.25	24.9
1.0	8.55	2.65	18.4	4.3	25.05
1.05	8.95	2.7	18.6	4.35	25.2
1.1	9.3	2.75	18.85	4.4	25.4
1.15	9.65	2.8	19.1	4.45	25.55
1.2	10.0	2.85	19.3	4.5	25.7
1.25	10.35	2.9	19.55	4.55	25.85
1.3	10.7	2.95	19.8	4.6	26.05
1.35	11.0	3.0	20.0	4.65	26.2
1.4	11.35	3.05	20.2	4.7	26.35
1.45	11.7	3.1	20.45	4.75	26.5
1.5	12.0	3.15	20.65	4.8	26.65
1.55	12.3	3.2	20.85	4.85	26.8
1.6	12.65	3.25	21.1	4.9	26.95
1.65	12.95	3.3	21.3	4.95	27.1
1.7	13.25	3.35	21.5	5.0	27.25

Method F.—This method is one that has been known under various designations and attributed to a variety of authors. It may be described as the method of direct approach through the skin and tissue to the foreign body, under fluoroscopic guidance; or, according to the apparatus used, as the method of cannula and trochar. While the

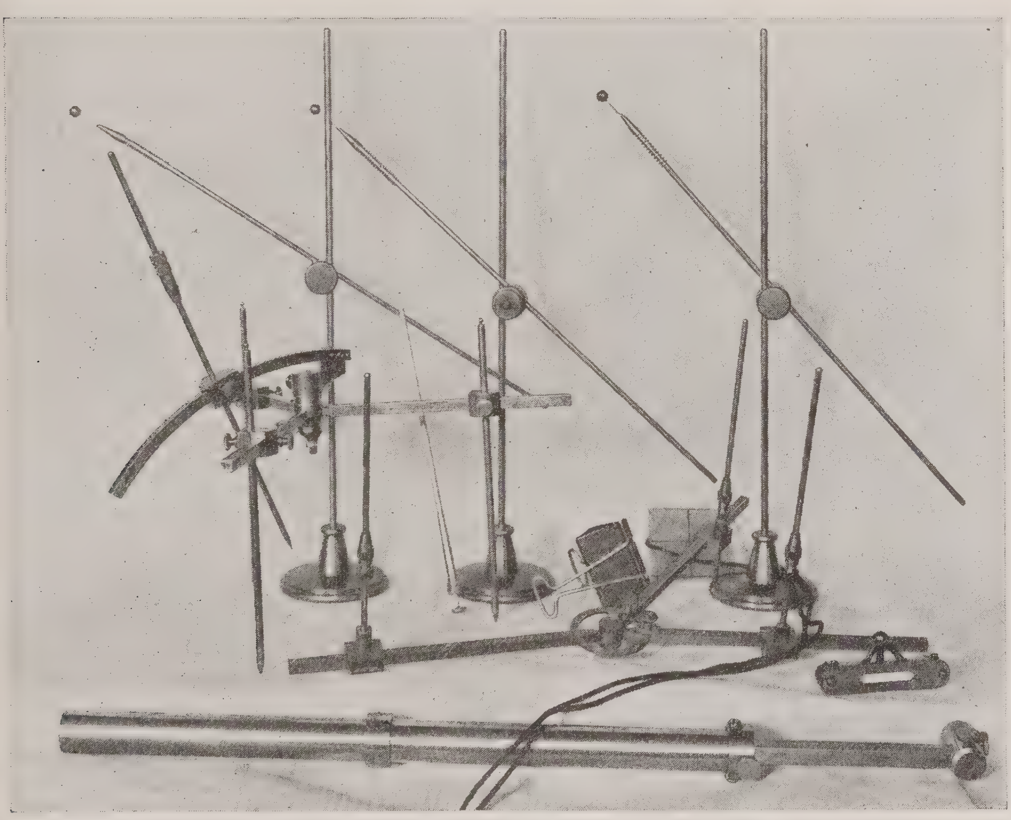


FIG. 127. Equipment supplied for use with Hirtz compass.

method has been advocated by some excellent surgeons and has naturally given good results in many cases, it is regarded by the Service as the least desirable of the methods adopted and it is urgently advised that it should never be used excepting in the hands of an operator who will either work under the direct supervision of a competent surgeon or anatomist, or who has acquired that degree of anatomi-

cal knowledge and surgical judgment which would permit of its use without danger to the patient.

The illustrations in various publications showing the in-

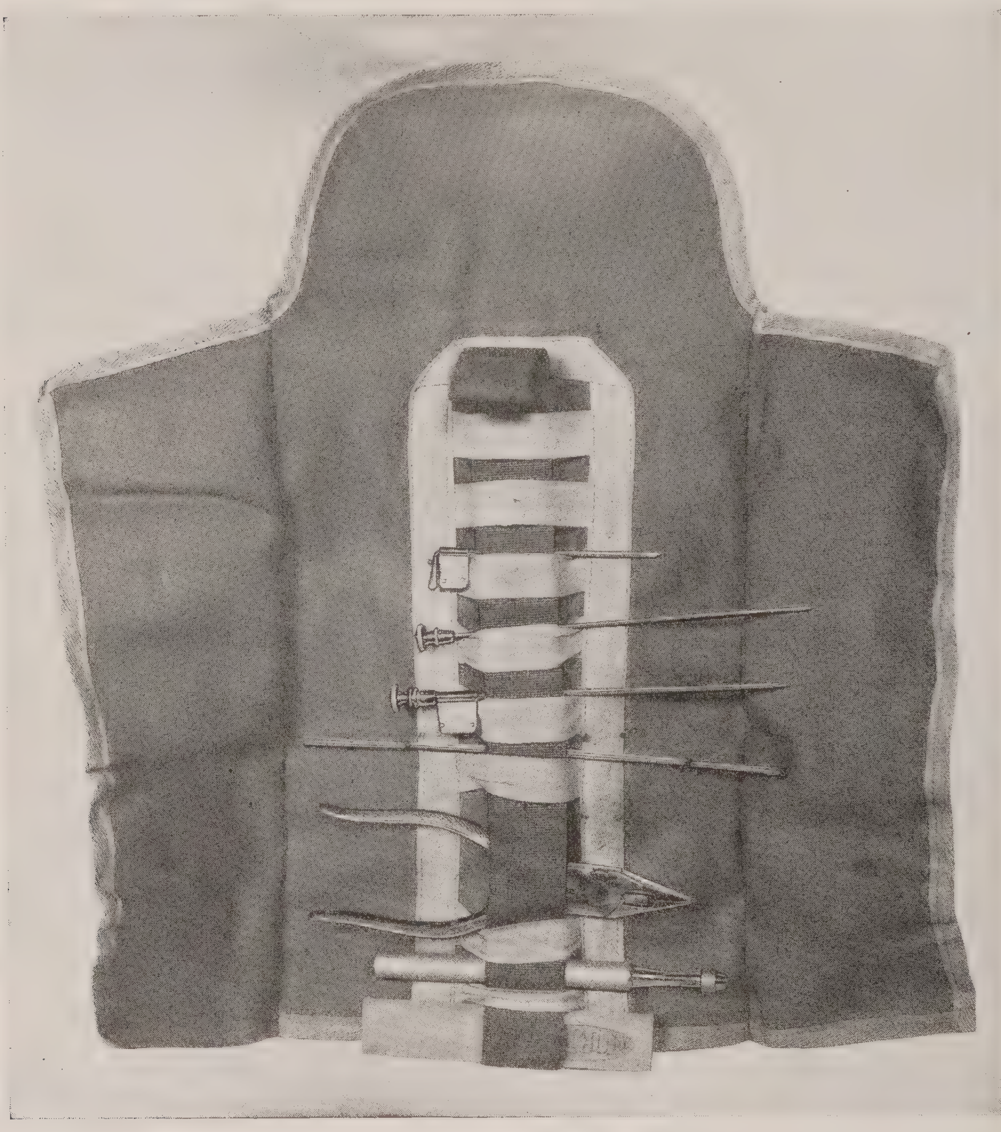


FIG. 128. Apparatus for *Method F.*

troduction of the instruments at an angle with the line of sight should be completely forgotten, as this method is bound to result in a considerable mutilation of the tissue before one is likely to come in contact with the projectile.

FIG. 129. Use of *Method F* with a perforated screen.

In using the standard army outfit, Fig. 128, one should bring the target vertically beneath the projectile, stop down the diaphragm to a moderate size, and lock the screen against all excepting vertical motion, with the cen-

tral perforation in the vertical ray passing through the projectile. Then insert the cannula and trochar through the perforation in the screen and, after puncturing the skin with the sharp pointed instrument, replace this by the obturator and press slowly and carefully down in a strictly vertical direction, until either contact with the projectile is felt or vision at two slight angles indicates that contact has been made, Fig. 129. After this, remove the trochar and pass the hooked piano wire or harpoon through the cannula, being sure that it passes beyond the end of the tube and that it is not withdrawn on removal of the cannula. While inserting the cannula it will best be held by use of a strong pair of forceps. These may lie flat upon the fluoroscopic screen and, in this way, the keeping of the cannula in a vertical position will be somewhat easier. The wire which has been inserted may, if one desires, be cut off a short distance, ¼ inch, above the skin, or it may be bent down close to the skin and, knowing the length of the original wire, the amount projecting gives the surgeon a definite idea of depth.

In the case of this method of localization but little in the way of explicit direction can be given, but it must be understood that the operator should know the line of approach with reference to possibility of bony obstruction and of dangerous proximity of vital organs, before he undertakes the work. Also he should invariably work with the instrument in line with the vertical ray, and not attempt to insert the instrument at an angle with this line. Use the sharp point only to puncture the skin and replace immediately by the obturator or blunt point, which may be inserted with far less danger of rupturing the blood vessels.

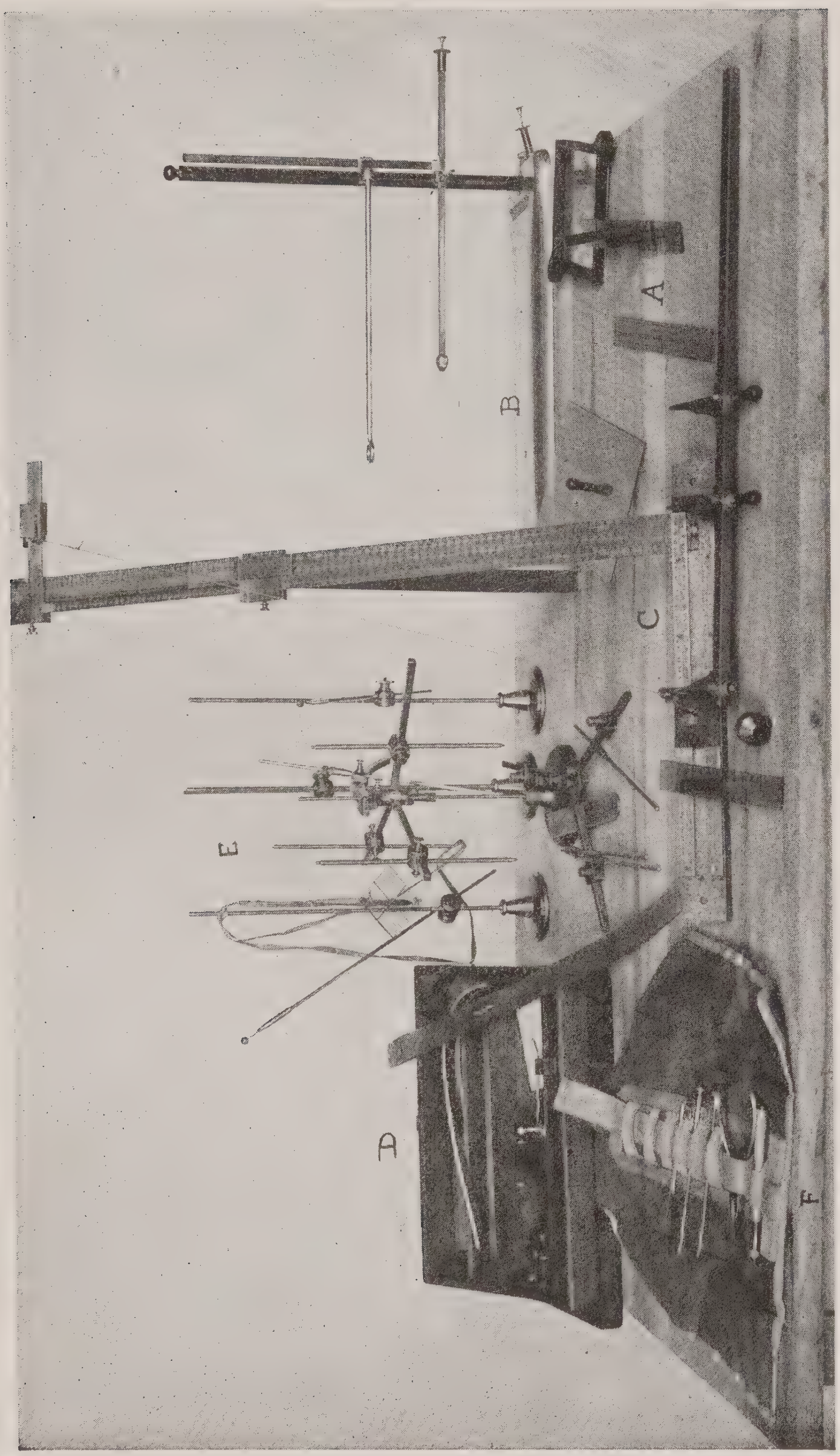


FIG. 130. Set of localization accessories supplied in the regular army outfit.

Fig. 130 shows the complete set of accessories for localization, as supplied and grouped according to the designating letters.

Fluoroscopic Assistance During Operation.—Several methods have been proposed for the utilization of the fluoroscope at the time of operation, especially where the mobility of the projectile in the tissue and the uncertainty of its position are such as to delay, unduly, the work of the surgeon. The methods so far proposed may be grouped as follows under four heads:

1. The x-ray work may be done in the surgical operating room, thus requiring the surgeon to operate in special light, which may be extinguished when he desires to examine fluoroscopically.

2. The patient may be returned to the x-ray room when the surgeon requires further information.

3. The roentgenologist may be called to the operating room for temporary assistance in pointing out the position of the projectile.

4. The operation may be performed with special forceps while using the fluoroscopic light as a guide.

Each of these propositions has its own difficulties and merits. The objections to the first are the bad fluoroscopic conditions which would be likely to prevail and the fact that the x-ray apparatus would be operated at low efficiency, being necessarily delayed by the surgical operation.

In the second, the transfer of the patient back to the x-ray room, provided a suitable stretcher top is used, may, of course, be accomplished, but it involves moving the patient back again for operation and the possible displacement of parts during the transfer.

The objection usually raised to number three is the requirement of x-ray apparatus in the operating room and the possible danger from sparks igniting an ether-air mix-

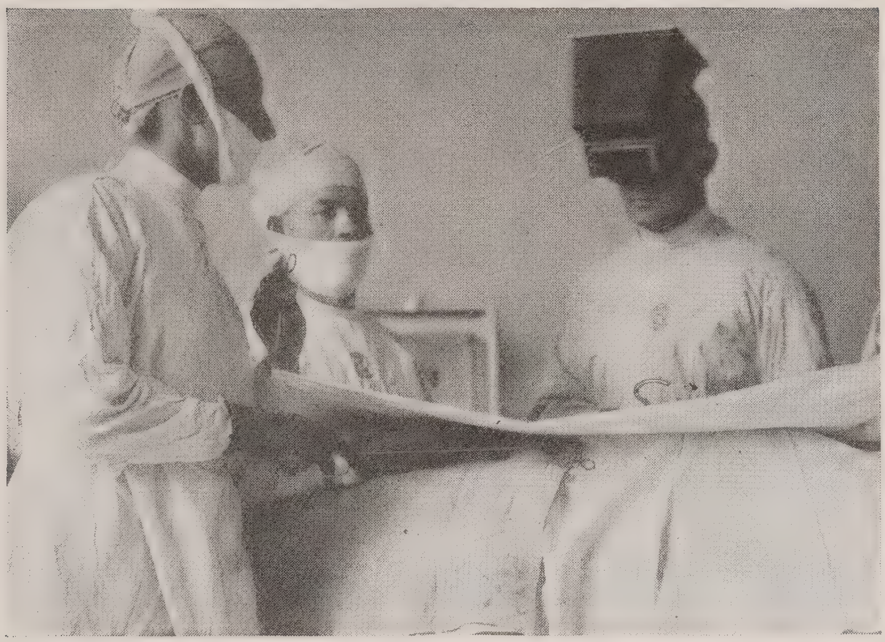


FIG. 131. Intermittent control. Roentgenologist with fluoroscope raised ready to lower it and proceed with examination.

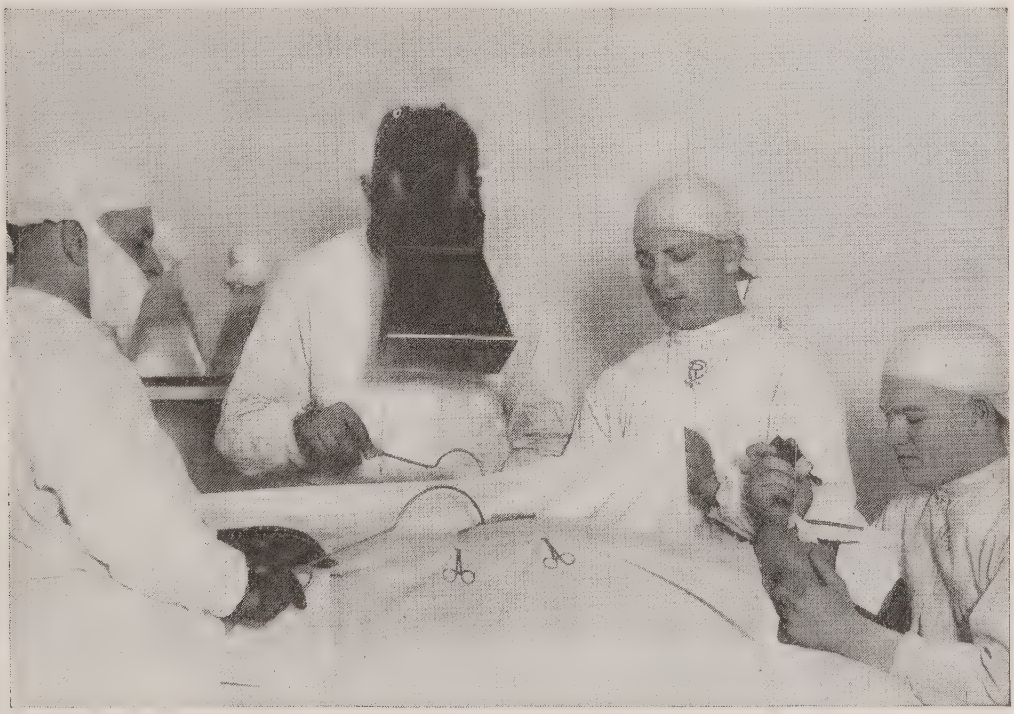


FIG. 132. Intermittent control. Surgeon and roentgenologist working simultaneously.

ture. The latter can be avoided either by making the x-ray apparatus spark proof or by avoiding these fumes from the anesthetic in the room. The roentgenologist must be supplied with a bonnet fluoroscope which automatically screens the eyes by suitably colored glasses when he seeks to find his way about a lighted room, and is automatically lifted or removed, when the fluoroscope comes into position.

In this case the process can perhaps be illustrated best by Figs. 131 and 132, showing also the type of indicator used by the roentgenologist and the surgeon. It is understood that the roentgenologist working above the sterile sheet can give an approximate indication, after which the surgeon, using a sterile pointer below the sheet, may, under fluoroscopic guidance by the roentgenologist, insert his indicator until contact is attained, after which the operation may proceed as before.

The fourth method is essentially one for the expert and will probably be of more value when a practical stereofluoroscope is provided.

The following extract from the report of the Senior Consultant in Roentgenology of the American Expeditionary Forces in France indicates the preparation which will be made for this class of work.

"The ordinary base hospital or portable table regularly furnished by the X-Ray Division of the Surgeon General's Department of the Army will serve admirably for this type of surgery, either operating with the bonnet fluoroscope in the usual bright light of the operating room, or by artificial light of suitable color in the fluoroscopic room of the x-ray department, with proper arrangements for conveniently extinguishing the artificial light and turning on the current going to the x-ray tube. An order has been placed for a hundred extra base hospital tables without the

screen support, to be issued to operating rooms for this very purpose, our anticipation being that the bonnet method will be far more popular than the open screen method. We have acquired in France a small supply of collapsible operating tables with aluminum tops, also designed for this special type of radio-surgical work. Lacking any of these tables, the roentgenologist will be able to improvise a suitable equipment by combining the bedside outfit with an ordinary stretcher, resting on the regular stretcher supports which will be available in the field.

"It is anticipated that the usual arrangement will be a base hospital table (without screen support) with overhead wire connections from the neighboring x-ray room, or there may be provided a special bedside unit without a tube stand with the tube under the table.

"For operations in the usual light of the operating room, there will be needed a bonnet fluoroscope, so arranged that when the roentgenologist is not actually working with the x-ray his accommodation will be preserved by means of dark glasses, automatically dropped before his eyes when the hood of the bonnet fluoroscope is turned up; a special metal pointer (*indicateur*) for the roentgenologist, one for the surgeon; and a forceps for projectile extraction of special design to protect the hands of the surgeon from the x-rays. A foot switch will be a help, but, in the absence of one, an assistant can turn the current on or off at will. Both hands of the roentgenologist must be free, so that he may be able to work."

The following paragraph and table are taken from an article by J. Metcalf and Keys-Wells in the *Lancet* of May 27, 1916.

Depth of Anatomical Landmarks Beneath the Skin.—Surgeons will find the table given below of value in determining the exact position of a foreign body in relation

to points on the skeleton. In their article published in connection with this table, the authors state that the surgeon often experiences many difficulties when operating for the removal of a foreign body even after the roentgenologist has made an accurate localization. Previous to the war, the surgeon studied the ultimate depth of his operation only with regard to certain surrounding anatomical landmarks, and not in terms of centimeters or inches beneath a point on the skin. If the roentgenologist reports a projectile as being 4.5 cm. from a point on the skin of the back overlying the transverse process of the 12th dorsal vertebra, the surgeon has little knowledge as to where this depth will lead him. If, however, the surgeon knows that the average depth of this structure is less than 4 cm. from the skin, he appreciates the fact that the projectile must lie in or just anterior to the transverse process. The objection is, of course, that individuals vary greatly in thickness of various parts, but the authors call attention to the fact that the soldier is selected after rigid examination and, as a result, the extremely thin and extremely obese are not present.

TABLE[1]

HEAD: LATERALLY *Incision*	DEPTH OF ANATOMICAL POSITION
Just above zygoma	2.5 cm. to sphenosquamosal suture
Just below zygoma	4 cm. to sphenoidal bone
To coronoid process or condyle of mandible	2.5 cm.
NECK: ANTEROPOSTERIORLY	
Through center of larynx	5 cm. to body of vertebra
3 cm. to side of center of larynx	4 cm. to transverse process of cervical vertebra
3 cm. to side of center of larynx	7.5 cm. total depth of neck
Through middle line of trachea just below cricoid	4 cm. to body of vertebra
3 cm. to side of center of trachea	4 cm. to transverse process of vertebra
From center of suprasternal notch	3 cm. to posterior border of manubrium

[1]Depths were given in inches in the original table, but have here been converted into centimeters.

NECK: LATERALLY	DEPTH OF ANATOMICAL POSITION
From center of middle of neck.	4 cm. to transverse process of vertebra
From center of middle of neck.	6 cm. to body of vertebra
From just below tip of mastoid process	6 cm. to body of 1st cervical
CHEST: SUPERIORLY	
From a point midway between root of neck and tip of acromion	5 cm. to apex of pleura, downwards
From a point midway between internal and external extremities and just behind posterior border of the clavicle	5 cm. to apex of pleura, downwards
CHEST: ANTERIORLY	
From center of lower border of clavicle backwards to subscapular fossa just clear of ribs	7.5 cm.
From a point just over tip of coracoid to subscapular fossa backwards	7.5 cm.
From a point 2.5 cm. external to sternoclavicular joint just below clavicle	3.5 cm. to 1st rib
From a point 2.5 cm. external to sternoclavicular joint just below clavicle	2 cm. to pleura
From a point 5 cm. external to sternoclavicular joint just below clavicle backwards	3 cm. to 1st rib
From a point 5 cm. external to sternoclavicular joint just below clavicle backwards	4.5 cm. to pleura
From a point 5 cm. below center of clavicle	5 cm. to pleura
CHEST: POSTERIORLY	
To supraspinous fossa	2.5 cm.
To intraspinous fossa	2 cm.
To transverse process of 7th cervical vertebra	4 cm.
To pleura level of 7th cervical vertebra	5 cm.
To anterior level of body of 7th cervical	7.5 cm.
To transverse process of 12th dorsal vertebra	3.5 cm.
To pleura level of 12th dorsal vertebra	5 cm.
To anterior level of body of 12th dorsal vertebra	8.5 cm.
ABDOMEN: THICKNESS OF WALL FROM FRONT	
1 cm. to either side of middle line just above umbilicus	2.5 cm.
1 cm. to either side of middle line just below umbilicus	3 cm.
Just internal to anterior superior spine to iliac fossa	7.5 cm.
Midway between anterior superior spine and pubic crest to front of acetabulum	5 cm.
ABDOMEN: THICKNESS OF WALL FROM SIDE	
On level of tip of 12th rib in line upwards from anterior superior spine	2.5 cm.
ABDOMEN: THICKNESS OF WALL FROM BACK	
To transverse process 3d lumbar	4.5 cm.
To anterior level of body of 3d lumbar	11 cm.
To anterior level of psoas muscle	13 cm.

HIP AND THIGH FROM FRONT	DEPTH OF ANATOMICAL POSITION
8 cm. below anterior superior spine to head of femur	6 cm.
8 cm. below anterior superior spine to neck of femur	5-7 cm.
15 cm. below anterior superior spine (level of lesser trochanter) to front of femur	4 cm.
To greater trochanter	11 cm.
To lesser trochanter	9 cm.
Brim of pelvis 2.5 cm. in front of sacroiliac synchondrosis	9.5 cm.
To anterior inferior spine	3 cm.
To spine of ischium	12.5
To ischial tuberosity	13 cm.
To anterior surface of line of junction of ascending ramus of ischium and descending of pubis	7 cm.

HIP AND THIGH FROM BACK	
To ischial tuberosity	6 cm.
To spine of sacrum on level of posterior superior spines of ilia	3 cm.
To sacral groove	5 cm.
To head of femur	5 cm.
To greater trochanter	9 cm.
To lesser trochanter	7.5 cm.
To brim of pelvis 25 cm. in front of sacroiliac synchondrosis	10 cm.
To anterior inferior spine	15 cm.
To spine of ischium	5 cm.
To posterior surface of junction of ascending ramus of ischium and descending ramus of pubis	11 cm.

Eye Localization.—In the case of foreign bodies in the eye very accurate localization is necessary, as knowledge of the exact position of the foreign body may mean the saving of an eye or the preservation of vision.

The simple Sweet-Bowen apparatus consists of two general parts: the base or head-rest, as illustrated in Fig. 133, and the localizer, as shown in outline drawing, Fig. 134.

The head-rest base is composed of the following parts:

1. A plate-slide tunnel, so constructed as to protect one-half of a 5 x 7 photographic plate while the other half is being exposed, and to protect the exposed half while the second exposure is being made.

2. Four rubber-tipped legs to raise the tunnel so that

it will act as a pillow to hold the patient's head level when lying on his side.

3. A plate-holder having a slide that will protect the plate from the ordinary light, but offer no resistance to the x-ray.

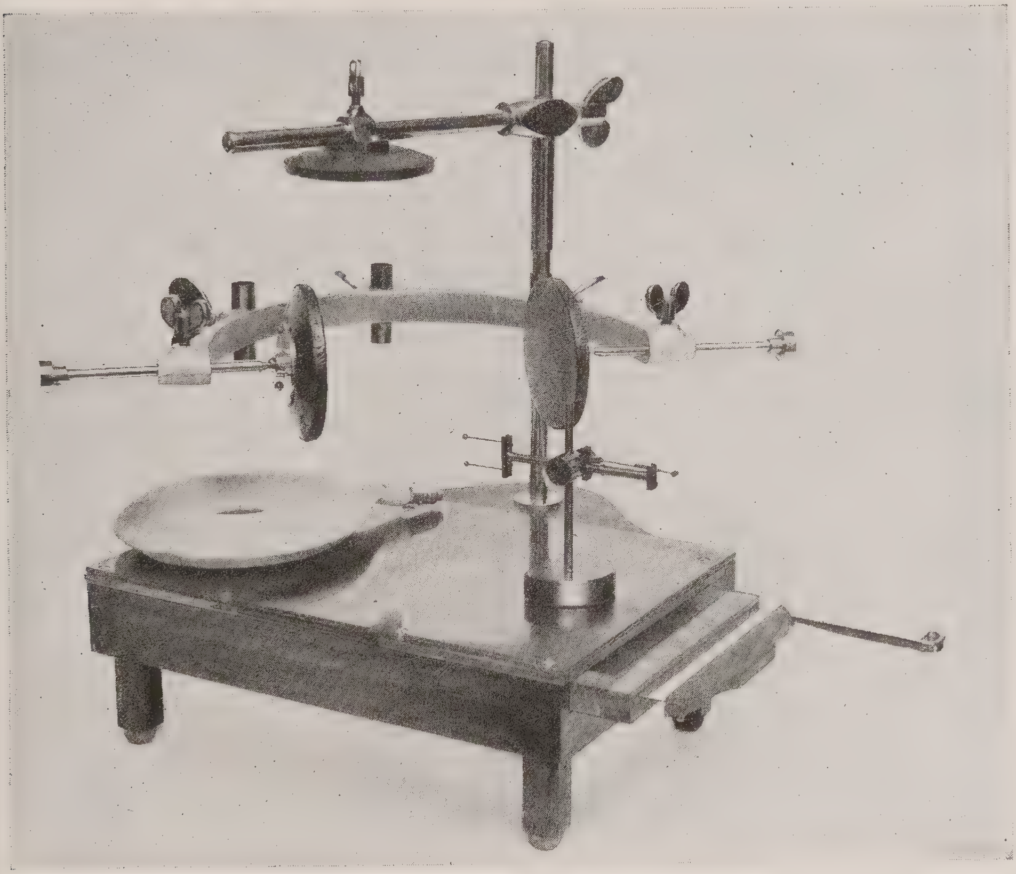


Fig. 133. Head rest for use with the eye localizer.

4. An arm or handle attached to the plate-holding slide to enable the operator to shift the plate the correct distance for each exposure, and to withdraw the same when both exposures have been made.

5. A pneumatic cushion for the comfort of the patient.

6. A double clamp to hold the patient's head and to prevent any horizontal movement.

7. A single vertical clamp to press the head downward upon the pneumatic cushion.

The localizer consists of:

1. A heavy metal base, Fig. 134.

2. An upright standard, *B*, to support the localizer and

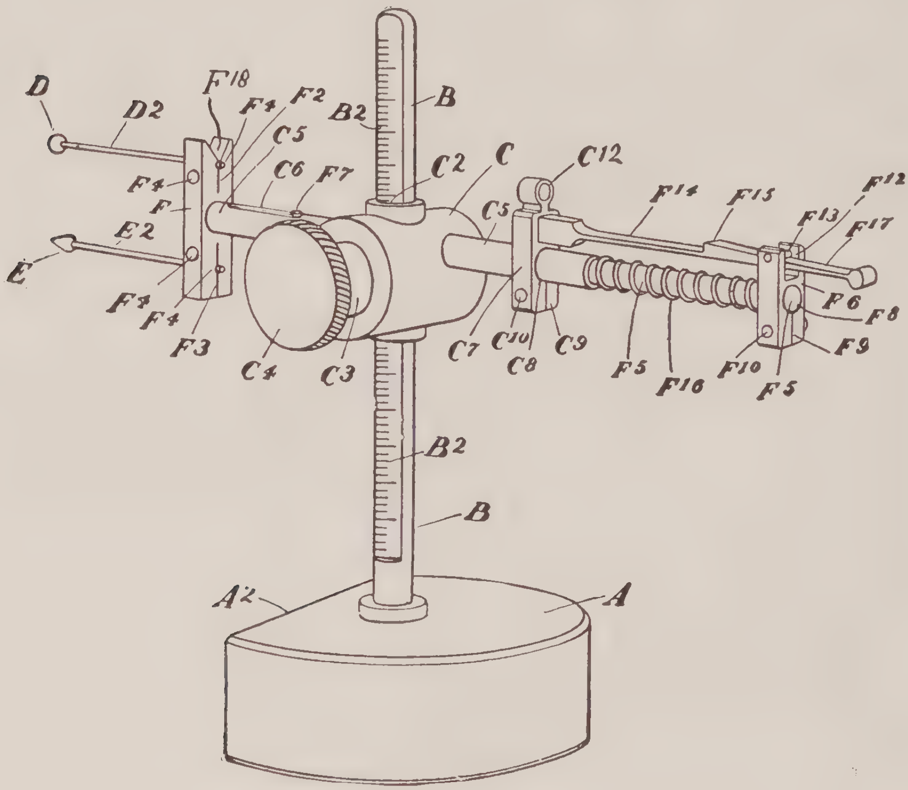


Fig. 134. Sweet eye localizer.

permit the same to be adjusted and held firmly at any desired height.

3. The indicator-ball *D* with its needle-supporting stem D^2, which, when properly adjusted to the center of an eye, will cast its shadow on the photographic plate and serve as a landmark to indicate the center of the cornea.

4. The metal tip *E*, of stem E^2 is made cone-shaped, so as to more easily differentiate its shadow from that of ball *D*. These indicators are permanently adjusted a

known distance apart (15 millimeters), and the base of the localizer is provided with two holes exactly 15 millimeters from center to center, which should be employed to verify this adjustment in case of doubt. When an x-ray plate is made of them obliquely, adjusted to an eye as above stated and as indicated in "front view" on the chart, we are enabled by their shadows to definitely locate the source and course of the rays of light (in relation to the chart) that caused the shadows. Also, the position of any foreign body that may show on the same plate can very easily be determined by the position of its shadow in relation to that of the ball and cone, because the exact position of the latter with reference to the chart is known and indicated (front view).

5. Tube C^{12} and notch F^{18} are sights similar to those used on a rifle, with which the operator can accurately align the center of the cornea of the afflicted eye with ball D and its supporting step D^2. F^{14} is a spring trigger which presses upwards against pin F^{13}. F^5 is the end of the rod to which the indicator-ball and cone D and E are attached by bracket F, the whole being supported by passing through tube C^5. Spring F^{14} being attached to stationary tube C^5 by means of bracket C^7, rod F^5 with bracket F^6 can be pressed forward until pin F^{13} is engaged by notch F^{15}.

6. By loosening set-screw C^4 the bracket C can be raised or lowered until ball D with its supporting stem D^2 is in exact alignment with the center of the cornea of the affected eye, and the screw is then tightened.

7. The patient is instructed to close his eyes, and the entire instrument with its base is slid forward until indicator-ball D presses into the eyelid approximately its thickness. The trigger F^{17} is then depressed to disengage notch F^{15} from pin F^{13}, when spring F^{16} will cause the rod

F^5 and indicator-ball D and cone E to rebound exactly ten millimeters, being restricted by knob F^7 in slot C^6. The subject and localizer are now in correct position for making the two necessary exposures.

First Exposure.—Place patient's head, affected eye downward, on the plate-holder base, with inflated cushion in position, as shown in illustration, being careful that the inflated cushion does not extend over the marked lines on the cover—otherwise it will cast a shadow on the photographic plate.

If the subject shows a tendency to move about, the horizontal clamp, as shown in Fig. 133, must be adjusted to the base of the head and forehead, otherwise the vertical clamp, as shown in illustrations herewith, will be sufficient. The double horizontal clamp can be adjusted for either eye by means of its two off-center holes and clamp screws.

Place the diaphragmed tube in position so that its central rays will exactly parallel the front vertical plane of the patient's eye, as shown in Fig. 135.

A plate, having previously been placed in the plate-holder, is now placed in the tunnel with the outer flange protruding, as shown in illustration. This will expose one-half of the plate to the action of the rays, while the other half will be protected for the second exposure.

The localizer (Fig. 134) is now placed on the stand in front of the affected eye; its trigger is "set" as already described and, after the indicator-ball has been adjusted to the plane of the cornea, the entire instrument is pushed forward on its base until the ball presses into the patient's closed eyelid approximately its thickness; the trigger spring is then released and the indicator-ball and cone recede exactly 10 millimeters, thereby permitting the patient to open his eyes and wink them in a natural manner. By referring

to localizer chart you will observe that due allowance of 10 millimeters has been made by placing the indicator-ball and cone just that far from the front plane of the

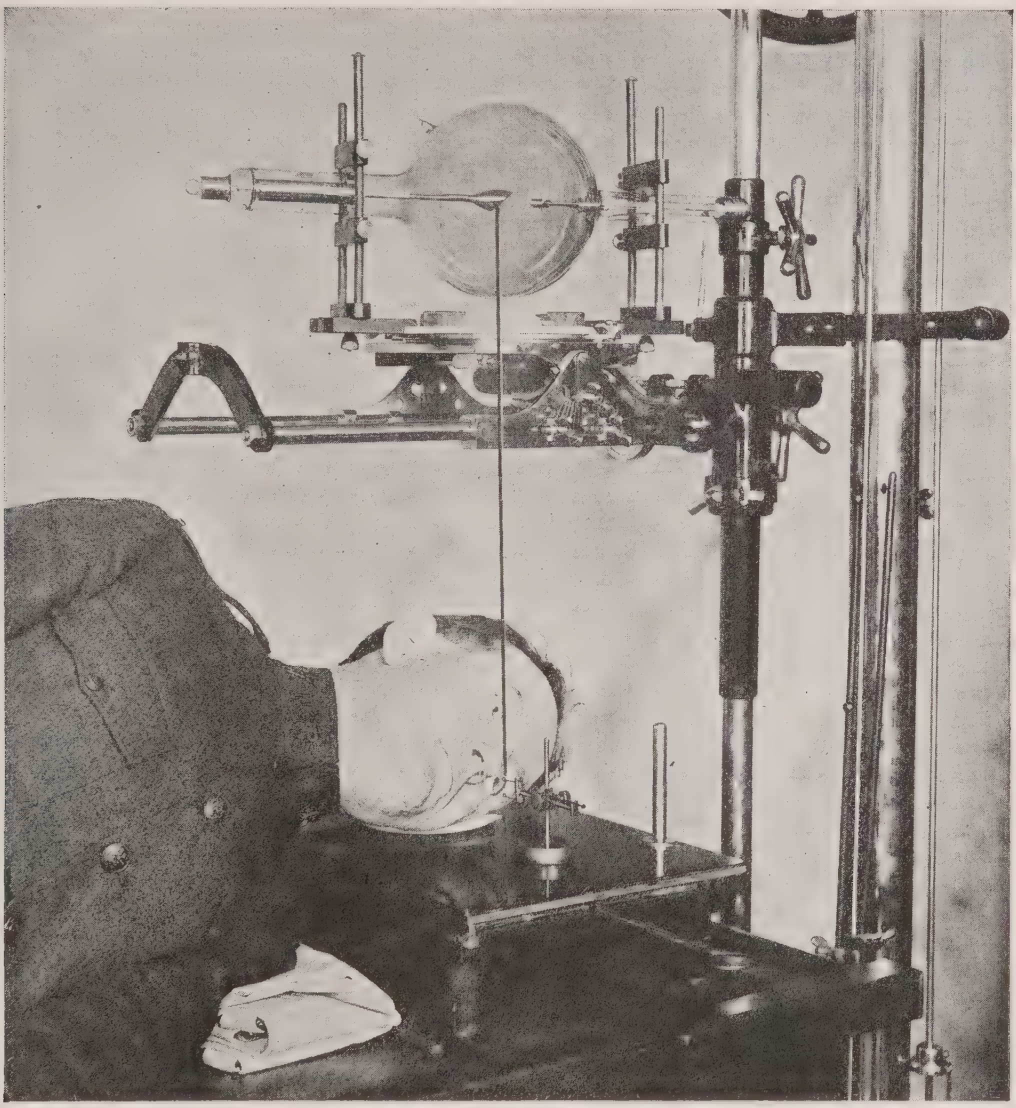


FIG. 135. Position for first exposure in localization of projectiles in the eye. Be certain that the tube is centered accurately over the cone so that both ball and cone will be superimposed.

cornea. It should also be borne in mind that the front of the cornea is 10 millimeters in front of the shadow of the indicator-ball, as shown in your negatives. The tube

is now centered over the localizing ball and cone so that the shadows of the two will coincide (Fig. 135).

Some object, such as a candle or a piece of white paper, that can readily be seen by the patient, should be placed in alignment with the sights of the indicator, but several feet removed therefrom, and the patient should be instructed

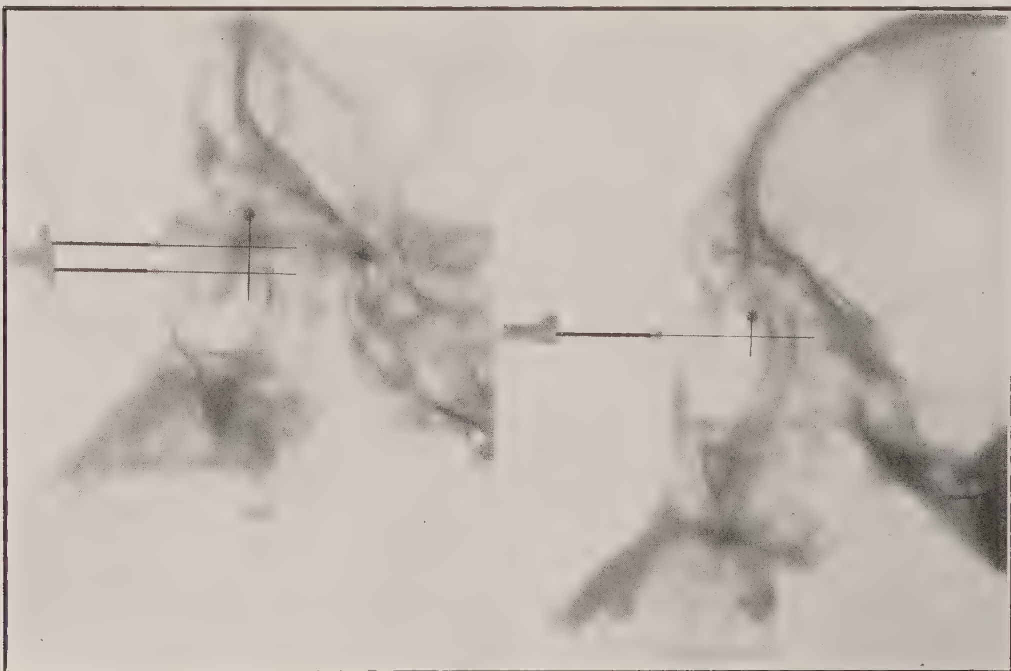


FIG. 136. Specimen plate of projectile in the eye illustrating the method of measurement.

to look constantly at this object while the two exposures are being made.

Second Exposure.—The first exposure having been made with the rays perpendicular to the plane of the plate and parallel to the patient's eye, thereby superimposing the shadows of the indicator-ball and cone and their supporting stems, as shown in the right-hand half of illustration (Fig. 136) the x-ray tube is then shifted toward the patient's feet four or five inches and tilted so that the indicator-rod points to the ball of the localizer, thereby

causing the central rays to pass obliquely through the center of the cornea of the patient's affected eye, as shown in

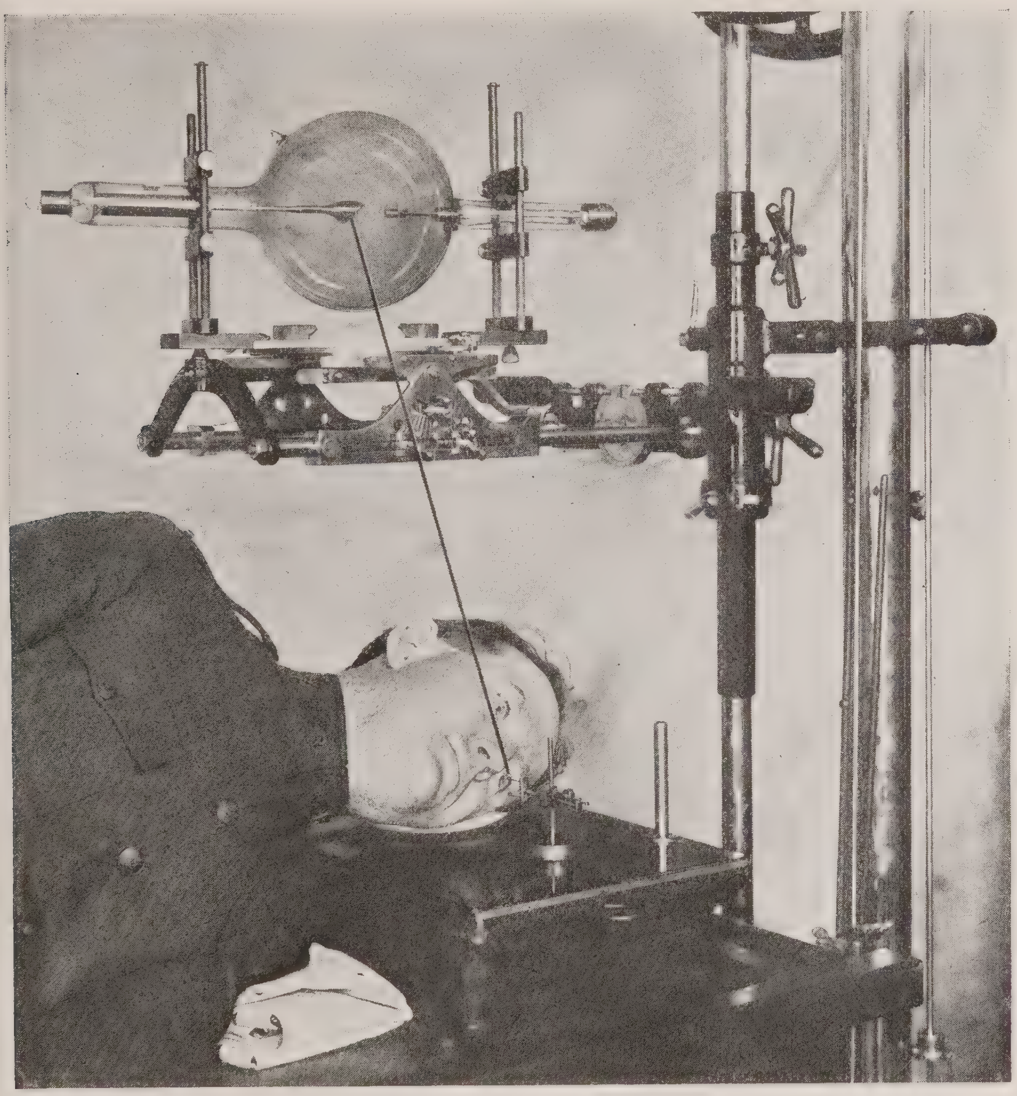
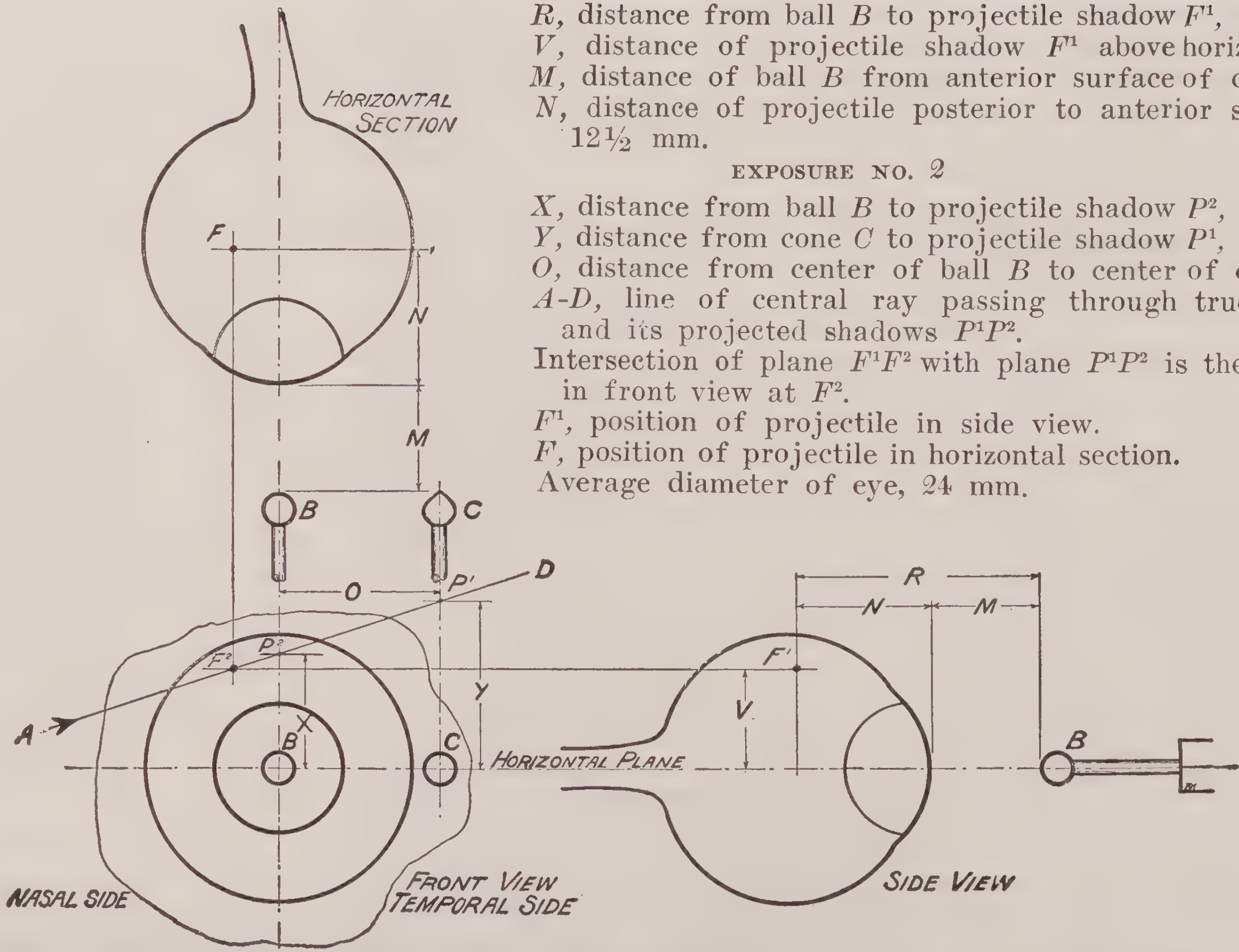


FIG. 137. Second exposure for localization of projectiles in the eye. Notice shift of tube in order to separate the shadows of ball and cone. Be careful not to produce any lateral shift. The tips of ball and cone must be kept in alignment.

Fig. 137. The photographic plate must now be shifted by pushing the plate-holder inward, by its handle, as far as it will go, thereby protecting that portion that was acted



EXPOSURE NO. 1

R, distance from ball *B* to projectile shadow F^1, 22½ mm.
V, distance of projectile shadow F^1 above horizontal plane, 9 mm.
M, distance of ball *B* from anterior surface of cornea, 10 mm.
N, distance of projectile posterior to anterior surface of cornea, 12½ mm.

EXPOSURE NO. 2

X, distance from ball *B* to projectile shadow P^2, 10½ mm.
Y, distance from cone *C* to projectile shadow P^1, 15½ mm.
O, distance from center of ball *B* to center of cone *C*, 15 mm.
A-D, line of central ray passing through true position of projectile and its projected shadows P^1P^2.
Intersection of plane F^1F^2 with plane P^1P^2 is the position of projectile in front view at F^2.
F^1, position of projectile in side view.
F, position of projectile in horizontal section.
Average diameter of eye, 24 mm.

FIG. 138. Schematic drawing of localizing chart illustrating the method of obtaining measurements.

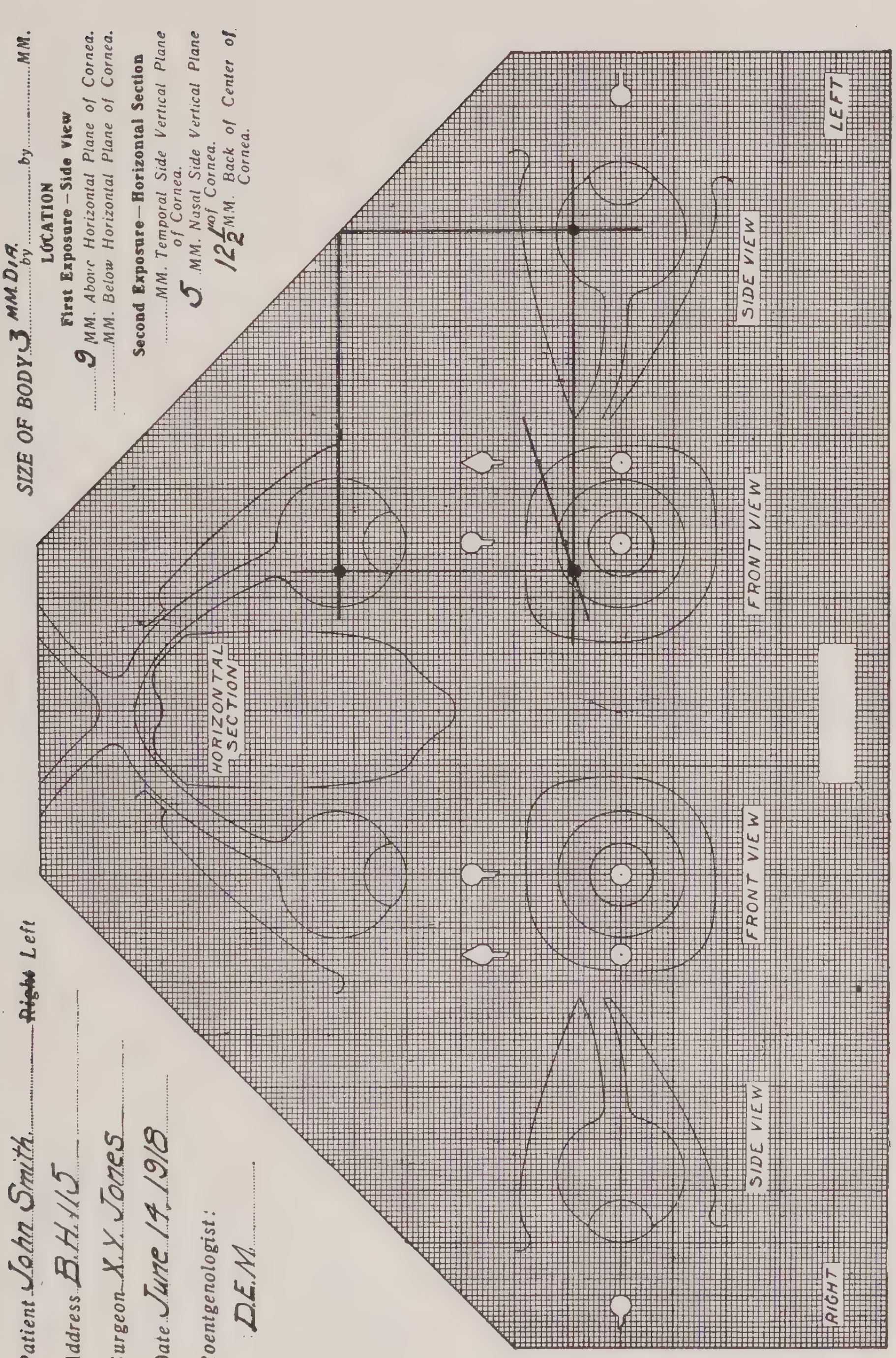


FIG. 139. Chart used in eye localization.

upon by the rays in the first exposure and bringing its unexposed half in proper position to receive the rays from the second exposure. In this position the second exposure is made with the rays falling obliquely upon the indicators, thereby separating their shadows, as shown in left half of illustration.

It should be remembered that it is not essential that the exposures be made with the tube at any specific distance from the plate, or even that it be the same distance for the two exposures. Neither is it important that the tube be shifted an exact or known distance for the second exposure, as by the use of the charts and Dr. Sweet's method the course of the ray is automatically established. This is shown by the line *A-D* through P^1 and P^2 of outline drawing, Fig. 138.

Charting the Plates.—In charting the plates the following method is pursued: Upon the negative (right-hand half of the illustration) which represents the first exposure, a line is drawn through the horizontal axis of the indicator-ball and cone which are here superimposed, thereby projecting their supporting stems and establishing the visual axis of the eye. Fig. 136.

A second line is drawn at right angles to the first through the center of the foreign body's shadow.

With a small pair of dividers step the distance from the edge of the indicator-ball to the intersection of the horizontal and vertical lines that you have just drawn. Then step this distance off on the diagram chart, making a dot with a pen, or a very sharp, hard pencil, to represent the exact distance (distance *R*, Fig. 138).

On the vertical line that has been drawn through the shadow of the foreign body (right-hand half of Fig. 136) measure the distance of the foreign body above or below

the horizontal line and indicate the same on the chart above or below the axis, distance V locating dot F^1.

Place another dot on the same horizontal plane and draw a line through these two dots, parallel to the axis, projecting into the front view as shown.

Since the position of localizer-ball B, as shown on the chart, side view, is the same as when the first plate was made, the location of the foreign body must be at point F^1. We have yet to establish its location to the nasal or temporal side.

Project a line vertically through point F^1 to the 45 degree angle (see Fig. 139), thence horizontally through the horizontal section.

Upon the negative (left-hand of illustration) which represents the second or oblique exposure, a line is drawn through the horizontal axis of both the ball and the cone, thereby projecting their supporting stems and establishing the relation of their horizontal planes to that of the foreign body.

A third line is drawn at right angles to the first two through the center of the foreign body shadow.

With your dividers measure the distance of the shadow of the foreign body above or below the horizontal plane of the shadow of the ball, and mark the same by a dot on the front view of the chart just above or below the center B, as indicated by distance X, because that was the relative position of the indicator ball when it cast the shadow. Measure the distance of the shadow of the foreign body above or below the horizontal plane of the shadow of the cone, and mark the same on the chart at the point above or below C indicated by distance Y because that was the relative position of the indicator cone when it cast the shadow.

A line drawn through dots P^1 and P^2 will represent

the true course of the rays in the second exposure, and its intersection with the projected line from the side view through the point F^1 will be the position of the foreign body when viewed from the front, while a vertical projection through the horizontal section shows the position of the foreign body to the nasal or temporal side at point F.

In these eye localizations a source of error is the fact that this is a schematic eye, constructed to correspond to the average eye which is about 24 millimeters in diameter, but this may vary 3 millimeters from the average.

Sometimes the variation can be measured with an opthalmoscope and corrections made, but ordinarily the eye is so injured that this is impossible, and we must assume that the eye corresponds to the schematic eye. This error, of course, would interfere only in those cases where the foreign body is located 1 or 2 millimeters inside or outside the sclera. In that event one would not be certain whether the foreign body was within or without the globe of the eye.

This point may often be determined in the following manner: Place the patient on his side with the afflicted side next to the plate and center the tube over the eye. Fix the vision of the good eye on a spot in a plane parallel to the plate, so placed that the eye is rotated toward the top of the head. Make an exposure of ½ the correct amount, then shift the vision to a point well toward the feet, still keeping the head fastened securely in place, and expose for the remainder of the necessary time.

If there are two images of the foreign body, it is certain that the foreign body moved with the eye and therefore must be in the globe.

It is barely possible for the foreign body to be in an ocular muscle and move, thereby giving two images, but

its position near the exterior and anterior portion of the globe would help differentiate this.

In an acute case where a localizing apparatus is not available, this method may be all that is necessary.

NEAREST POINT METHOD OF LOCALIZATION

Owing to the enormous pressure of work on the roentgenologist in an advance hospital during periods of great activity on the front, it is necessary to utilize the simplest and most rapid method of localization consistent with working accuracy. One method, not described in the manual, that has met with considerable favor in rapid approximate determination of location and depth, is the so-called "nearest point" method.

This method consists in palpating, under fluoroscopic observation, the soft tissue surrounding the projectile. The instrument used for this palpation is a wooden rod about ten inches long with a wooden screw or some similar piece of metal at the end. Under the screen the wood is almost invisible and the only plain shadow is that cast by the metal. By the movement of the projectile under pressure on the tissue surrounding it, and the amount of pressure used, the operator is able to judge with fair accuracy what point on the skin is nearest the projectile and the depth from that point. Obviously, palpation at a very near point will ordinarily cause much greater movement of the projectile than will palpation at a more remote part of the skin surface. Likewise, palpation will cause greater displacement in the very soft tissues than it will in the firmer tissues.

Skill in this method increases with continued use, and a sense of pressure is developed that proves a valuable aid to speed and accuracy. To the beginner it is recommended that he combine with palpation the principle of Method B, by shifting his tube and observing relative displacements of the projectile and the palpating stick.

The nearest point method is applicable to localization of projectiles in the soft tissues of the extremities, the axilla, scrotum, and buttocks, but not to the more vital and less palpable regions of the head, thorax, and abdominal cavities. By practice one becomes accustomed to palpating the soft tissues around the foreign body, and by what are termed light and deep palpation to determining the depth of the projectile from the nearest point on the skin surface. Even if the foreign body cannot be displaced by pressure with the palpating stick this information is often of great value, showing that the projectile must be in a joint, against the bone, or embedded in deep tissue.

This method is, in brief, adapted to localization in the extremities and soft parts of the body under advance hospital conditions, where rapid examination of the patients is a matter of prime importance.

BONES AND JOINTS

Fractures.—A fracture may be defined as a break in the texture of a bone or, more briefly, as a solution of continuity.

The study of fractures with the aid of the x-ray enables us to decide: first, whether a fracture is present or absent; second, the number and relation of the broken fragments, so that the best mechanical measures can be selected for replacement. After a retentive dressing has been applied, it is easy to study the results of treatment without waiting for the test of healing and restoration of function.

From a radiographic standpoint fractures may be classified into: first, *simple fractures,* where the bone is broken in two pieces; second, *comminuted fractures,* where the bone is broken into many pieces. Simple fractures may be further classified according to the direction of the fracture line: first, where the line of cleavage is transverse; second, oblique; third, longitudinal; fourth, combinations of the preceding varieties. Naturally the comminuted fracture is more common in military service than in civil life. In military service there is to be seen frequently the effect of high-speed bullets upon bones. The difference between high-speed projectiles and small projectiles of low velocity is quite striking. In the former the results simulate an explosive action evidenced in the marked comminution and shattering of the osseous tissue. Small lead bullets, as a .22, usually cause only slight injury to bones,

and very often the effect of the contact is seen rather in the deforming of the bullet than in the shattering of the bone.

Fractures may be studied by the x-ray either by the fluoroscopic method or by the plate method. Each has its advantages and disadvantages.

Fluoroscopic Method.—The advantages of the fluoroscopic method are, primarily, its convenience and quickness of execution, without the delay of waiting for the development of plates. It allows of a rapid survey of the entire body. It is cheap as compared with the cost of a number of plates. Its principal disadvantage lies in the fact that it does not always show clearly the texture of bones, so that fractures of slight displacement are not readily shown. This is especially true in fleshy individuals and in parts of the body where the bones are enveloped in a good deal of soft tissue. Fractures of small bones, as transverse fractures of the scaphoid or longitudinal fractures of the head of the radius, may easily escape notice. Impacted fractures also of the lower end of the radius and of the surgical neck of the humerus may be seen so indistinctly on the screen that there may occur a reasonable doubt as to their presence.

Plate Method.—The chief advantage of the plate method is that it affords an exact study of the cancellous tissue of the bones. It also gives a permanent record of the case, so that the condition may be observed by others. As in the examination of the gastro-intestinal tract, the greatest amount of information is often best obtained by a combination of the two methods.

The determination of the part of the body to be radiographed will naturally depend, first, upon the clinical history, if one can be obtained, and second, upon the usual signs of fracture on physical examination. If a patient

can be examined on the fluoroscopic table, the fluoroscope will assist in deciding on the area to be radiographed. It is evident, however, that some types of subperiosteal fracture, for example, fractures of the lower end of the fibula, may be present without screen evidence.

In radiographic examination of fractures, the adherence to a routine and established type of technique is of considerable advantage. One of the most essential points in this technique is the choice of a suitable ray; by this is meant a ray of penetration sufficient to properly display the internal structure of the bone. Such a ray will be given off by a tube having an equivalent spark gap of four to five inches. Next to the choice of the proper penetration will be the estimation of the correct time of exposure. The next factor in the production of suitable plates is immobilization. If attention is not paid to this, the twitching of the wounded muscles and the voluntary attempt on the part of the patient to keep the part quiet will result in muscular tremor which will blur the bone detail. The immobilization can be obtained most easily by weighting the parts above and below the area to be examined by suitable sand-bags. These sand-bags should not be completely filled. They can then be packed around the limb in order to secure the greatest quiet. If sand-bags are not obtainable, the use of strips of adhesive plaster above and below the examined area will be found useful. Wide bandages passed around the part and then tied on the under surface of the table may also be used. If one is working with the tube above the table, cotton pads or an inflated rubber bag may be placed between the cone of the tube-holder and the affected part for compression.

It is very important that plates should be labeled at the time of examination. In the hurry of darkroom technique plates are sometimes reversed, so that it is not always pos-

sible to tell at a glance whether the plate is of the right or left leg. Accordingly, with each exposure a lead letter *R* or a lead letter *L* should be placed upon the plate to designate which limb is being radiographed. It is of further advantage in lateral plates, especially of the femur, to mark the anterior border with suitable lead letters, so that the relative position of the fragments can be told at a glance. The necessity of doing this arises from the fact that oftentimes plates are examined when the radiographer is absent, and those observing the plates may not be skilled in their interpretation. With the careful labeling of plates serious mistakes may often be avoided.

In examining fractures which we have reason to suspect are comminuted, or which may be complicated with the presence of a foreign body, the value of stereoscopic plates cannot be overestimated. These give a good idea of the true relation of the fragments, and if the foreign body is present, show its position in three planes.

Location of Tube.—In considering the examination of special parts of the body, we must consider the technique from two separate standpoints. First, the examination may be conducted with the patient lying upon a table, the tube being placed above the part to be x-rayed and the plate underneath. Second, if the examiner is provided with an apparatus by which the tube is contained in a tube box underneath the table, the rays are then directed from below upward. Each method has certain advantages and disadvantages. The advantage of the first position is that one can see at a glance the relation of the tube to the part to be radiographed, and he is able to make use of the central rays. The advantage of using the central rays is to minimize distortion. While this distortion may have only a comparatively slight importance in plates made of simple fractures, yet in plates of comminuted frac-

tures, especially those complicated with foreign bodies, the question of distortion assumes considerable importance. A further advantage of using the tube stand is that in certain parts of the body it is advantageous to employ oblique rays. For example, in radiographing the foot, it is often necessary to employ oblique radiation in order to properly separate the shadows of the metatarsal bones. The degree of obliquity and the angle at which the rays will strike the part examined can be much more easily told by the use of a tube stand than by the use of a box underneath the table containing the tube. Another great advantage of the ordinary tube stand is that the tube can be shifted so that the rays pass laterally, permitting of lateral exposures of the ankle, knee, femur, and arm without disturbance of the patient. In fractures of the femur and knee with plates made at the bedside of the patient, this will oftentimes be a point of great advantage. The disadvantages of this method are, first, the necessity of raising the limb to insert the plate underneath, and, second, the necessity of protecting the plate from moist dressings. This objection can be easily overcome by placing the plate in an aluminum plate-holder.

The advantages of working with the tube beneath the table are the fact that the plate can be supported immediately above the injured member and that no lifting of the limb while the patient is on the table is necessary. If the tube box below the table is used, it is necessary to have some mechanical pointer attached to the box so that one knows the axis of the central rays. In the making of stereoscopic radiograms many operators prefer the tube above the patient. Most of the types of American apparatus are made for radiographing the patient from above downward, while many of the types of the Continental and the English, have the tube below the table.

Position for Exposure.—The illustrations show briefly the positions in which the different parts should be radiographed. These positions may be adopted as a routine in the majority of cases, and there is an advantage in following a routine plan. The individual case may, however, demand a departure, in which case, a safe rule to follow is that the injured part should be as close to the plate as possible and the vertical ray should enter immediately over the center of this area.

The comfort of the patient must be kept constantly in mind, and if an arm cannot be completely extended, it is possible to demonstrate lateral displacement of fragments by the anteroposterior exposure even if the elbow is flexed at a right angle. The point to remember is, that it is impossible even with stereoscopic plates to tell accurately the amount of displacement that may be present in the region of a joint, such as an elbow or knee, if the plates have been made in one direction only.

In the case of the spine the best results are obtained by raying a comparatively small area at a time with a medium sized cone. For the lateral view it is almost essential that one should use an intensifying screen and remove the tube to a considerable distance from the plate, at least thirty inches.

Radiographs Made Through Splints or Casts.—In radiographing parts of the body enveloped in splints or casts, there is presented, oftentimes, a difficult problem. For purposes of exact diagnosis it is always best, when possible, to remove any splints or casts. If the examination is made for determining the position after reduction, the dressing should be left on. The length of exposure is to be increased so as to compensate for the extra amount of material which has to be penetrated. Some splint materials, for example, yucca board, contain particles of extra den-

sity which, when superimposed on the shadows of the bone, render the detection of subperiosteal fractures difficult. It often occurs that the radiographer has to decide whether callus is present or absent in a limb enveloped in a plaster splint. It can be stated that this is oftentimes impossible to be decided, as the varying densities of the folds of plaster induce shadows which may simulate the appearance of callus. Sometimes when a limb has a splint on one side only, the rays can be directed so that the shadow of the bone can be wholly or partly isolated from the shadow of the splint. In elbows confined with a right-angle metallic splint, the metal may cast a shadow over the part especially interesting, and here in the interest of exact diagnosis it is best to secure permission to remove the splint. Dry plaster is more easily penetrated by the ray than moist plaster, so that it is always best to x-ray a limb in a plaster cast after the cast has become thoroughly dry. The position of the fragments of long bones of course can be accurately told even when enveloped in a wet plaster cast, but it is not to be expected that fine detail and the presence or absence of callus can be made out without the removal of the cast. Where the examination has to be made in only one direction the plates should be stereoscopic.

Splints, casts, dressings, bandages, etc., should never be disturbed by the roentgenologist. If they have to be removed, this should be done by, or under the direction of, the surgeon.

The Appearance of Callus.—Changes in the periosteal surface appear very early after injury, sometimes being seen after a period of four or five days. These periosteal changes vary in proportion to the amount of displacement. If a fracture is of the subperiosteal type, or if the fragments have been accurately coapted, periosteal changes

will be small, and not extend far from the seat of fracture. If the fracture is transverse, with over-riding, or if it is comminuted with displacement, we may find periosteal changes extending a number of inches away from the seat of injury. We often find, especially in the lower leg, difficulty in telling whether there has been enough repair to allow the patient to walk upon the leg. Careful inspection of the plate may show nothing but the position of the fragments, without any periosteal change. In these cases, it is difficult to tell from the radiogram alone whether union has taken place.

Reports.—In writing reports of x-ray plates for fractures, it is essential to describe *first* the area shown by the plate with the anatomic parts of the bone examined; *second,* to give a description of the traumatic pathology shown; *third,* a statement as to the condition of the bone, or bones, and of the soft parts outside of the area described in the second heading. In the report the manner in which the plate is made should be described so that this can be taken account of in considering the interpretation. For example, if a lateral plate is made, this fact should be mentioned at the beginning of the description. A description of the traumatic pathology should embrace, first of all, the part of the bone involved; second, the type of fracture, whether transverse, oblique or longitudinal; third, whether comminution is present and the number and size of the fragments. In all cases the relative position of the fragments should be described. If the fracture is complicated by the presence of a foreign body, this should be stated, with the size, shape and position, and its relative position to the bone fragments.

Particular attention should be paid to the question as to whether the fracture line involves joint surfaces. Prog-

nosis and treatment are materially affected in this type of injury.

If it is doubtful after an examination of all the plates whether a fracture is present or absent, this doubt should be plainly stated and the reasons for it given. If the uncertainty is based on lack of penetration or blurring due to movement, a second exposure should be made. If splints were present at the time of examination, their appearance should be described and special note made as to whether the shadow of the splint complicates the interpretation.

Negative Reports.—If the examination does not reveal the ordinary x-ray evidences of fracture, this should be stated with a definite description of the area shown by the plate. For example, a negative report stating that there is present no fracture of the tibia or fibula should not be made unless the plate shows the entire length of the tibia and fibula. If the limb is rayed in only one direction, note should be made of this and the conclusion should be stated that no disturbance of the outline of the bone is shown in this *one* view.

X-Ray Osteology.—To become proficient in the interpretation of plates, constant use should be made of the drawings and descriptions in standard anatomies, supplemented, if possible, by recourse to the study of the skeleton.

Epiphyses.—While in military radiography the question of the appearance of the bones during their development will not often be raised, yet it is best to remember that during the growing period, when the bones are in formation, their appearance may be different from the fully formed adult type. The different standard anatomies give tables under which are described the development of the bones and the age at which the epiphyseal lines become ossified. In the young adult the appearance of the crest of the ilium should be borne in mind, as ossification here

takes place at the age of eighteen to twenty. In cases of doubt as to whether the epiphyseal line is to be differentiated from a fracture line, a plate made of the uninjured limb for purposes of comparison is of the utmost importance.

Plate Defects.—The interpreter of x-ray plates should be constantly on his guard against confusing plate defects with fracture lines. While it is unusual for such confusion to arise, still, scratches upon the plates have been mistaken for solutions of continuity; artefacts due to air bubbles have been confused with foreign bodies.

Conclusions to Be Drawn from Plates Influencing Methods of Re-position.—It can be said that some clinicians do not derive from the study of the plates all the information which the plates afford. Here the conference between the experienced roentgenologist and the clinician is of the greatest benefit to the patient. A careful study of the plate, with a full understanding of the problems of re-position, will oftentimes obviate the question of operative interference.

Setting of Fractures under the Fluoroscope.—In the reduction of fractures the aid of the fluoroscope during manipulation may be of value. Important precautions are, however, to be observed in this procedure. If the patient is under ether anesthesia, precautions should be taken against the ignition of the ether vapor by electric sparks from the high tension current. The danger of this is in direct proportion to the lack of ventilation in the operating room. If the high tension wires are covered with thick insulating material and loose connections are avoided so that there is no tendency for sparks to occur, the danger is minimized.

The operator and his assistant should be protected as completely as possible against radiation. This may be

done by the use of x-ray proof gloves, x-ray proof aprons, suitable lead glass over the fluoroscopic screen, and the use of as small a cone of x-ray light as will enable the ends of the bones to be properly seen. While this method is of great value when properly done, yet one should be slow about drawing inferences as to correct position from fluoroscopic examination in a single direction.

Radiographs with Patient in Bed.—It often occurs that in patients whose general condition does not warrant their removal to the radiographic table, the x-ray examination should preferably be made with the patient in his bed. It also happens that after a reduction has been made and extension has been present for a number of hours, it is highly desirable to find out if the fragments are in position. If the patient is moved to the x-ray room and the extension discontinued, it is obvious that the plates obtained may not represent the true condition of the fragments as afforded by the treatment in the patient's bed. The standard army bedside unit was designed especially to take care of this class of work without disturbing the patient more than is absolutely necessary. It is, of course, not always possible to make the examination fluoroscopically at the bedside owing to the presence of the bed, which is likely to contain metal. In many cases, however, a lateral view may be secured fluoroscopically, and radiographic work can be done from above downward or laterally without difficulty. It should be observed that the limitations formerly present on portable apparatus such that heads, hips, etc., could not be successfully radiographed do not apply to this unit. By using the proper exposure, either with or without intensifying screens, radiographs of all parts of the body may be successfuly made, provided the part can be immobilized. It will be found that with good intensifying screens and double-coated films the time of

exposure will differ but little from that used with the large machines without screens.

Dislocations.—Examinations of the body for the determination as to whether a dislocation is present or absent involve the same general applications of radiography as in the determination of the presence of fractures. The same principles of suitable penetration of the rays, immobilization as completely as possible of the part under examination, the employment of the stereoscopic method, and care in the interpretation of the plates obtained possess equal importance. In the detection of dislocations, the fluoroscopic method is of value in dislocations of the larger joints, as the shoulder, the elbow, knee and ankle. Dislocations of the carpal bones and the metatarsal bones are not usually seen easily with the fluoroscope. The advantage of the fluoroscopic method in examination of the large joints, for example, the shoulder, lies in the fact that the position of the tube is easily shifted so that the rays will strike the joint at different angles. An observation of the shoulder joint from one angle may produce a distortion which may be deceiving. In general, it may be said that the central rays should go through the joint surface under examination, and that they should strike the plate at a perpendicular. Oblique radiation, when used, should have its results interpreted very carefully.

Reduction of Dislocations with Fluoroscopic Aid.—Reduction of dislocations under fluoroscopic guidance is especially advantageous; the operator can see constantly the relation of the two articulating surfaces and better plan his attempts at reduction. It is obvious that the same precautions should be observed as in manipulation of fractures under the fluoroscope. In all dislocations of large joints it is best to have stereoscopic plates of the joint, not only to determine the relative positions of the

articular surfaces but also to determine their integrity. Sprain fractures are a frequent complication of dislocations, and, if they can be detected, this knowledge assists materially in making the prognosis.

Fluoroscopy vs. Radiography.—In fractures and dislocations radiography is the method of choice, since it reveals detail impossible to obtain on the screen and forms a permanent record. The chief value of the fluoroscopic method, which can demonstrate only gross lesions, lies in its simplicity, speed, and comparative inexpensiveness. It is of value in positive diagnosis but is absolutely of no value when the findings are negative.

Fracture of the Skull.—The shape of the skull and its elasticity, the close fitting covering of skin, muscle, fascia and periosteum on the outside, and the pressure of the intracranial contents and the dura on the inside, tend to immediately replace and maintain fractures in position. For this reason, we find fractures indicating only slight bony injury, the grave lesion being to the blood vessels, intracranial nerves, dura and brain substance and the secondary conditions arising therefrom; the presence or absence of fracture, in such cases, fades into insignificance except as a clue to the site of the injury and a guide for surgical procedure.

Varying from this class, we have the other extreme; namely, those having an extensive bony lesion, as in depressed or perforating fractures, with or without injury to the underlying structures. In such cases, the location and character of the fracture must be considered. Here the force is consumed in breaking bone at the point of contact, the effect being dependent upon the amount of force, the point of injury and the character of the body producing the fracture.

Between the two definite forms above mentioned, there

is much variance in the importance of the bony injury.

Fractures of the skull may be divided into those of the vault and those involving the base. In over fifty per cent of the cases examined radiographically there is found a combination of both. Fracture of the vault may be due to direct or indirect violence or it may be an extension from the base. There have been various theories advanced relating to these fractures, such as, Aran's theory of irradiation, the bursting theory, fractures by contrecoup and the Rawling theory of direct violence. It would seem as though each applied, as a causative factor, to certain classes of fracture of the skull. Experience shows that cases which are able to reach the roentgenologist present a fairly constant effect of direct violence, the point of impact receiving the maximum amount of bony injury; from this point, we have radiating fracture lines which seek the weaker parts of the skull in the immediate neighborhood.

The common fractures of the skull are described as: fissured, comminuted, diastasis of the sutures, depressed and perforated. The frequency with which these fractures are mistaken for various other conditions, especially in cases of coma, calls for a method which will make a rapid and positive diagnosis. On account of the many difficulties which are encountered in the correct diagnosis of head lesions the routine x-ray examination of the skull is of the greatest importance in all head injuries. It offers an actual visual demonstration of the presence or absence of fracture, its location, character and extent.

Traumatic skull injuries should have systematic x-ray examination. If such examinations were made in all cases of head injuries, statistics would show a much greater percentage of fractures than at present. In a series of 300 cases in the writer's experience, twenty per cent showed fracture.

When a case of head injury is referred to the roentgenologist for examination, the patient is often in an irritable, semiconscious or comatose condition. Extreme patience and perseverance are required, and it is even frequently necessary to administer a hypodermic of Magendie's solution. It must be borne in mind that the *minimum amount of disturbance and movement* is essential.

In skull examinations, the patient's head must be absolutely fixed and, if possible, all respiratory movement overcome. If the objective symptoms, such as bleeding from the ear, nose or mouth, laceration of the scalp, hematoma or paralysis be present, they are a clue to the possible site of the fracture, and attention is naturally directed toward that area; this must not mislead one, however, for every examination should cover the frontal, the parietotemporal, the occipital and basilar regions.

It should be constantly borne in mind that examination of the skull requires a considerable amount of radiation for each plate taken. On this account it is absolutely necessary to use at least one millimeter of aluminum as a filter and to keep in mind the cumulative effect of the exposures and the fact that the areas receiving radiation during the different examinations overlap to some extent.

Where the required current of 40 ma. at a 5-inch gap cannot be secured, one should not attempt to do the work at a lower gap, but should maintain the gap at the expense of current. Thus, if one must use 5 ma. instead of 40, still at a 5-inch gap, the time of exposure at the same distance must be eight times as long. For 10 ma. four times as long. The objectionable feature in this procedure is the increased difficulty of immobilization for the longer periods.

Frontal Region.—In the examination of the frontal region, we should endeavor to show as much of the vertical

plate of the frontal bone as possible. The patient is placed on the table flat on the abdomen with face resting on the plate. The glabella should be in contact with the plate. An imaginary line running through the glabella and symphysis of the jaw should be parallel to the axis of the plate. The head should then be firmly fixed either by clamps or

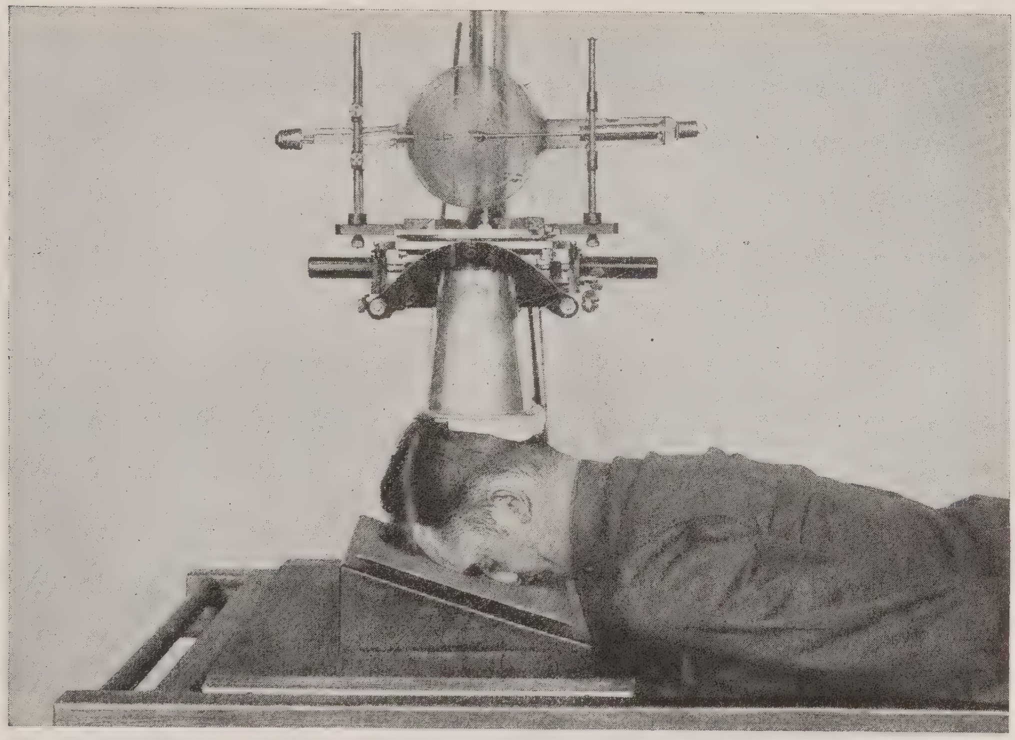


FIG. 140. Position for examination of frontal region of skull.

sand-bags, care being taken not to rotate the head during this immobilization. The tube should then be adjusted so that the ray through the center of the diaphragm passes through the center of the glabella. Target-plate distance should be about 22 inches. Fig. 140.

A 5-inch spark-gap is used, forty to forty-five milliamperes and an exposure of about six to eight seconds. In the majority of cases this procedure will give satisfactory plates of the frontal region.

If circumstances require the use of the portable table, the fluoroscopic screen should be replaced by the tube holder. Should it be necessary to use the portable outfit with a 5-inch gap and ten milliamperes, the exposure would be about thirty to thirty-five seconds. The bedside unit being limited to 5-inch spark-gap and five milli-

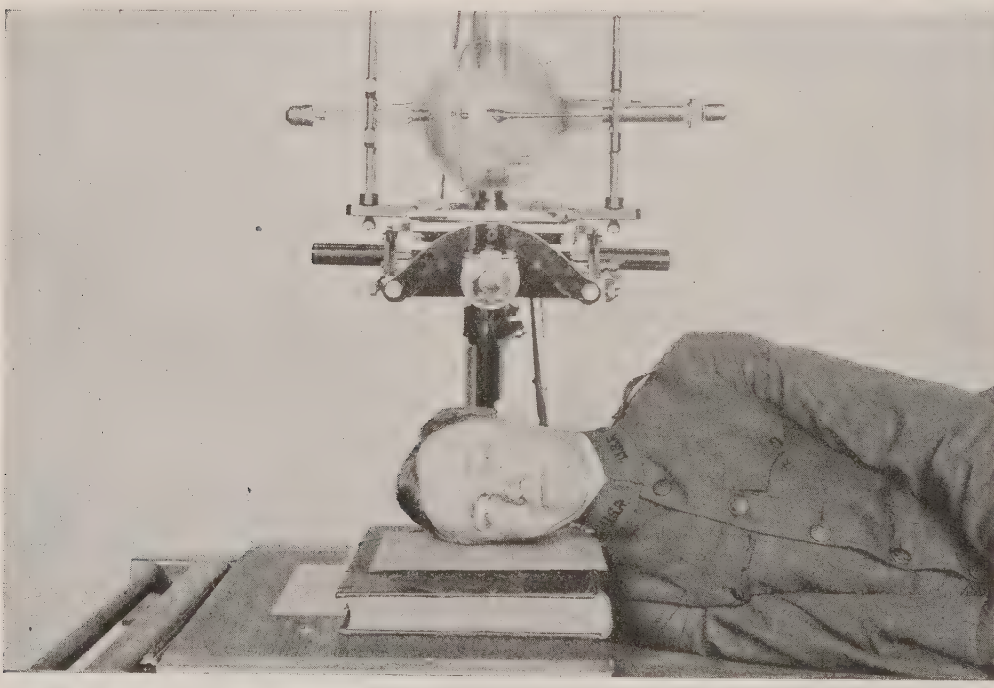


FIG. 141. Position for examination of temporoparietal region of skull.

amperes, it would be best to use an intensifying screen and a properly modified exposure.

Temporoparietal.—In examining the temporoparietal region, we should show that portion of the skull lying between the sagittal suture above, the coronal suture anteriorly, the lambdoid suture posteriorly and including the entire temporal bone. Both sides of the head must be examined. The patient lies on his side with neck slightly extended, the center of the temporal region resting upon

the plate. The head is raised or lowered until a line extending from the glabella to the symphysis of the lower jaw is parallel with the plate. The tube is adjusted over the center of the temporal region, perpendicular to the plate at a distance of *twenty-four* inches. The head should be securely clamped or held by a weighted bandage. Fig. 141.

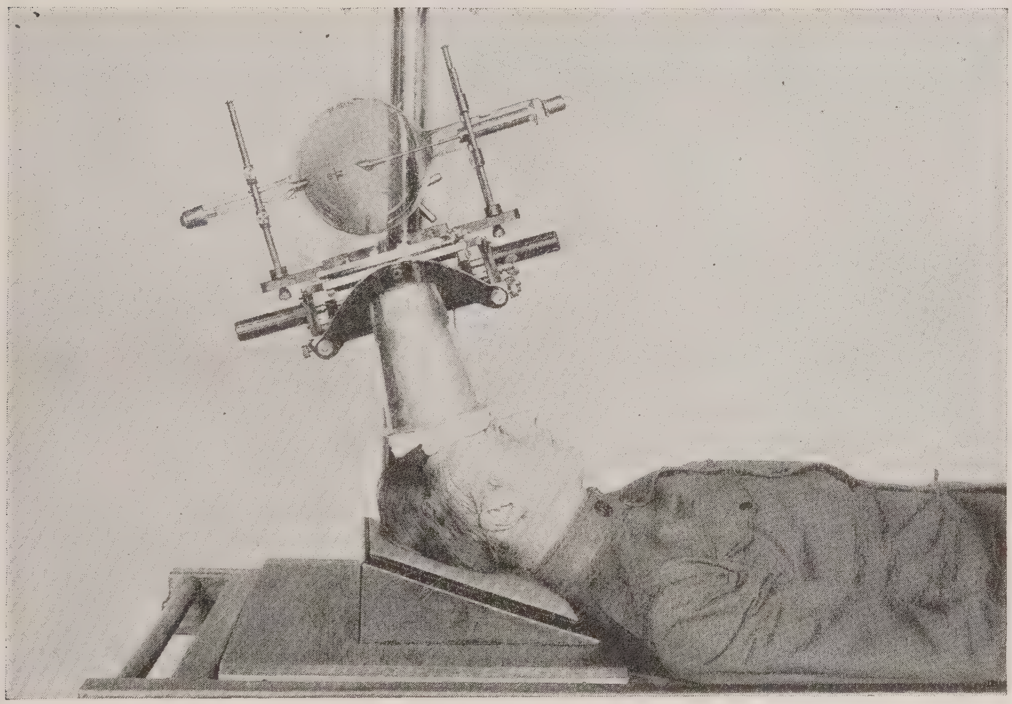


FIG. 142. Position for examination of posterior (occipital) region of skull.

The same electrical conditions govern the tube as when examining the frontal region, except that it is seldom necessary to make the exposure longer than three or four seconds.

Posterior Region.—When examining the posterior region, we must bring out with clear detail the entire occipital bone, with the lambdoid sutures like an inverted V above, the mastoids on either side and the foramen magnum below. The patient lies on his back on the top of the

table with the occiput flat down on the plate, the center of the occipital bone being placed in contact with the plate. The head should be slightly flexed so that the central ray (tube tilted 15° toward the feet) enters the forehead just above and between the frontal eminences. If a cone is used, the lower border of the cone should not extend below the supraorbital ridges. The head is clamped or held in position by a weighted bandage. Fig. 142. An exposure of about nine seconds is made with a tube taking about forty milliamperes and with a gap of five inches.

Base Region.—In cases of suspected fracture of the base the vertical technique, as advocated by D. R. Bowen for examination of the sphenoidal sinuses, may be used with slight modification.

To carry out this method it is necessary to elevate the shoulders a few inches so that extension of the neck is obtained. The head should be so placed that a line drawn from the glabella to the external auditory meatus is parallel to the plate.

The tube is then adjusted so that the central ray through a two-inch opening in a lead diaphragm is centered midway between the midlarynx and the symphysis of the jaw. This central ray will be in a plane about one inch in front of the external auditory meatus. The target should be at a distance of about twenty-two inches from the plate or film. The patient's head must be securely immobilized and clamped if necessary. Fig. 143. With the tube taking forty milliamperes at a 5-inch gap, an exposure of about ten seconds will be required.

Having obtained satisfactory plates, it is necessary to have the experience and anatomical knowledge to make the correct interpretation. In reading plates of the base of the skull, beginning behind, we see the foramen magnum and within it the odontoid process of the axis. Just for-

ward of this opening, on either side, the mastoids are distinctly reproduced with the associated shadows of the petrous portion of the temporal bone. Anterior to this is a clear view of the middle fossa. If the chin is not too extended, the anterior fossa can be seen in front of the overlying shadow of the lower jaw. Fractures of the zygo-

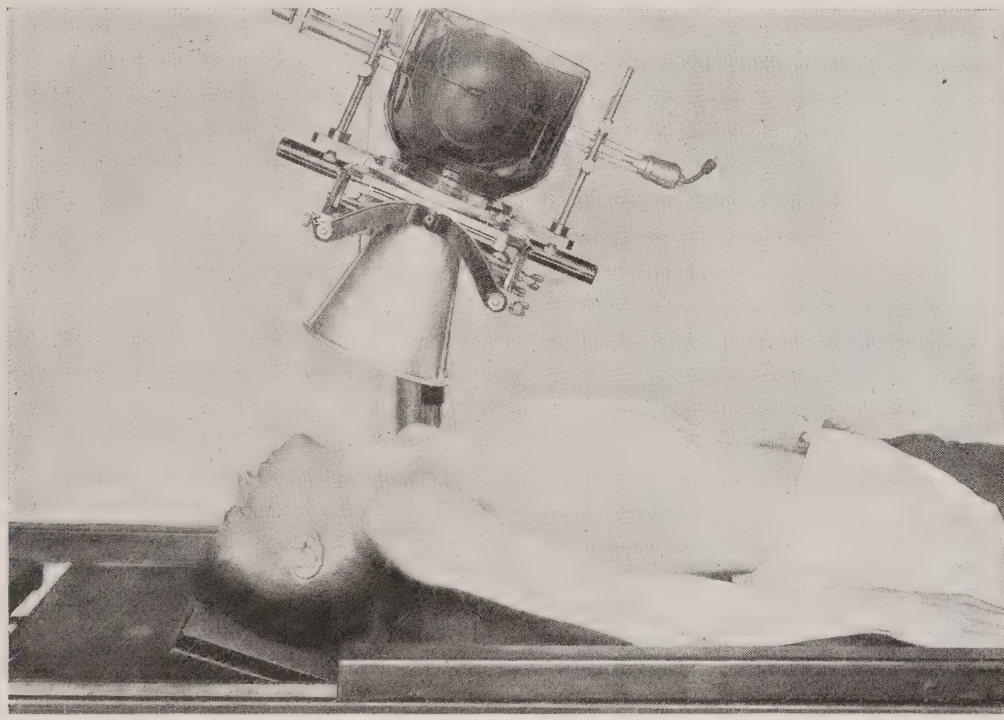


FIG. 143. Position for examination of basilar region of skull.

matic arch, with the extent of displacement, are usually beautifully shown in radiograms of the base.

In the interpretation of the frontal, lateral and occipital regions one must note the suture markings and the normal radiating lines cast by the grooves on the inner table of the skull, which accommodate the meningeal vessels; these grooves spread fan-shaped from an anterior point backward. The shadows cast by the diploic spaces, between

the inner and outer tables of the skull, are lines extending vertically upward from the base, interlacing at the top and terminating as a rule in an anterior and a posterior lake. They are directly at variance with the shadows representing the meningeal grooves.

Fractures usually show as dark, sharply cut lines of varying width, depending upon the extent of separation; they may be vertical, horizontal or curved, but seldom directed in the same manner as the blood vessel grooves.

In addition, we wish to especially emphasize the value of the stereoscopic examination in these head injuries. It is often difficult in cases of slight depression for the surgeon to decide whether to interfere or not. The presence or absence of symptoms of intracranial pressure and the actual demonstration of the condition of the inner table of the skull, with the amount of depression, if any, are vital facts which should be considered before a decision is made.

Lateral stereoscopic plates aid in tracing the fracture line into the base and locating the termination. In the common penetrating fractures of the vertical plate of the frontal bone and those cases of linear fracture extending into the roof of the orbit, they are of extreme value, as giving the most accurate estimate of the seriousness of the bony injury.

Examination of Spine.—On account of the importance and frequency of spinal injuries, some special instruction may be found desirable. The roentgenologist who is unfamiliar with the indications of anatomy as shown on the x-ray plate with reference to the spine would do well to review carefully the anatomy and study with considerable care plates made of normal individuals in which the spine is clearly shown. Attention is also called to paragraph on page 320 with reference to certain abnormalities which are of frequent occurrence.

Generally speaking, fluoroscopic examination is of little value in examinations of the spine on account of the thickness of tissue and the necessarily small degree of contrast which may be secured. It is frequently, however, of value to use a small screen in the examination of the cervical region.

On account of the considerable number of bony projections and spinous processes and the peculiar curvature of the column as a whole, it is frequently difficult to secure plates depicting the vertebræ with sufficient accuracy for diagnostic purposes, and unless great care is taken to follow a definite procedure, information can hardly be secured by comparison of plates.

Fig. 144 shows an outline of the spinal column with its common divisions into cervical, thoracic and lumbar. The lateral view clearly indicates the necessary superposition of shadows, and it can be readily seen how slight modifications in position may result in very considerable deformation of shadow outline. Possibly the best general rule would be that the central portion of the beam used should be, as near as possible, perpendicular to the spinal column, and in all cases the target must be symmetrically placed over the spine.

Attention must also be called to the fact that the patient should be moved and handled as little as possible and always with extreme care, as not only are these spinal injuries likely to be extremely painful, but careless handling is very likely to bring about injury to the cord even if this were not present before examination.

Most of the examinations are made in the supine position, and it is essential to have the plate or film come as nearly as possible in contact with the body so as to avoid distortion and hazing of the shadow by reason of distance of the spine from the plate. In some cases it will be neces-

sary to turn the patient on the side or partially so for lateral examination, in which case special care will be needed.

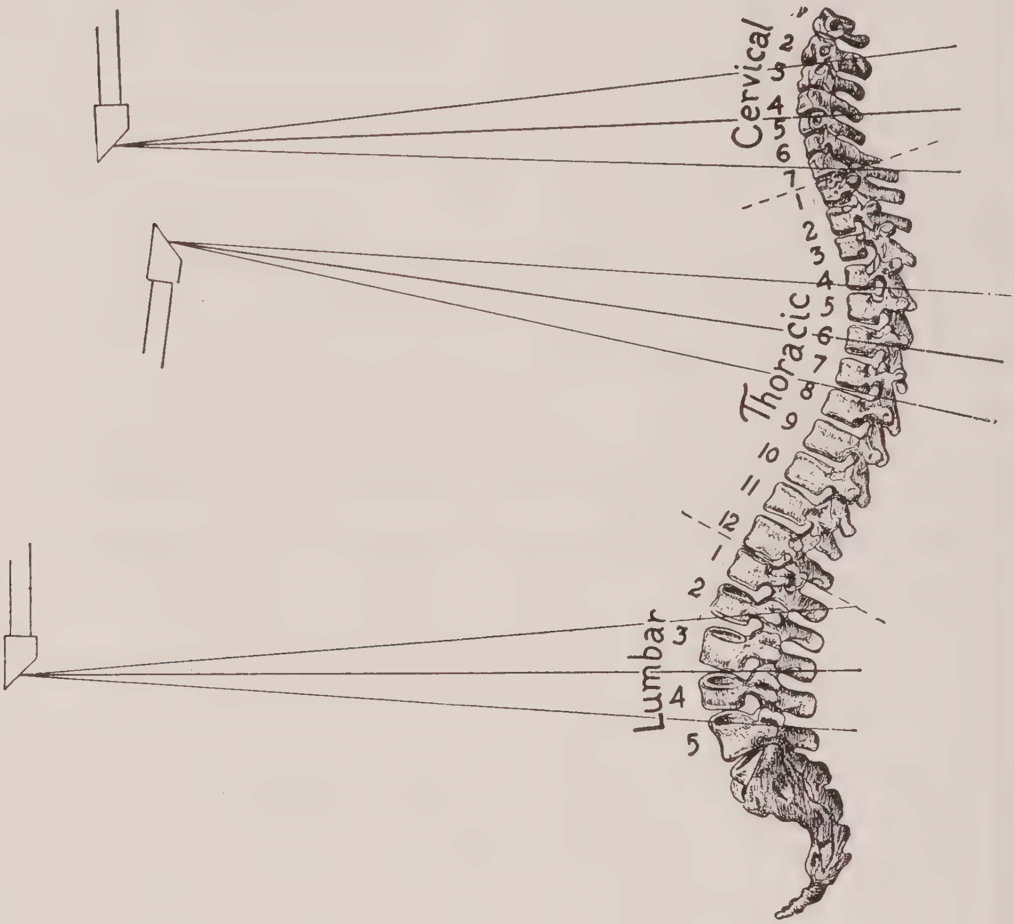


FIG. 144. The normal spine has general divisions into cervical, thoracic and lumbar. The projection lines from targets do not represent standard positions, but simply illustrate the projection, if the central rays are perpendicular to spinal column. The operator can vary opening of cone, size of plate and position so as to bring out special features desired.

Fractures of the spine may be simple or compound, due to either direct or indirect violence. The most common is the compression fracture of the body of the vertebræ,

which occurs more frequently in the lower thoracic and upper lumbar regions. It may also be seen in the mid-cervicals. In a large percentage of this type of fracture there is an associated dislocation, the displacement in the cervicals being anteroposterior, while the thoracic and lumbar are more frequently displaced laterally.

Transverse or spinous processes may be fractured either by direct violence or by muscular action. This class of injuries is usually caused by forcible bending, as in extreme flexion, resulting from a fall. These fractures may involve one or more vertebræ; the bodies are somewhat flattened longitudinally and usually show a wedge-shaped formation. In certain cases there is a true splintering of the bone instead of crushing of the body, and in these cases there is great danger of injury to the cord, due to the action of bony fragments.

As a general rule no preparation of the patient is required excepting in the case of the lower thoracic and lumbar vertebræ, in which case a thorough cleansing by cathartic is desirable.

It is always well to make stereoscopic plates when in doubt, and in this case some variation in the time of exposure of the two plates may be of advantage.

The following brief summary of the positions and exposures is given and it is suggested that the roentgenologist who has not had experience in this work undertake to make plates in these positions with normal subjects, when time permits, so as to more fully understand the work and be able to carry it out with the least amount of disturbance to the patient.

Upper Cervicals.—Fig. 145. The head should be supported by the wooden wedge used in frontal sinus work, or otherwise, the head being semiflexed. The mouth may be held open by a large cork, placed as far back between

the molars on one side as possible. Care should be taken to fix the head in position and the central ray should be perpendicular to the plate, passing directly through the open mouth. A distance of 22 inches will be found desirable and an approximate exposure, at 40 ma., 5-inch

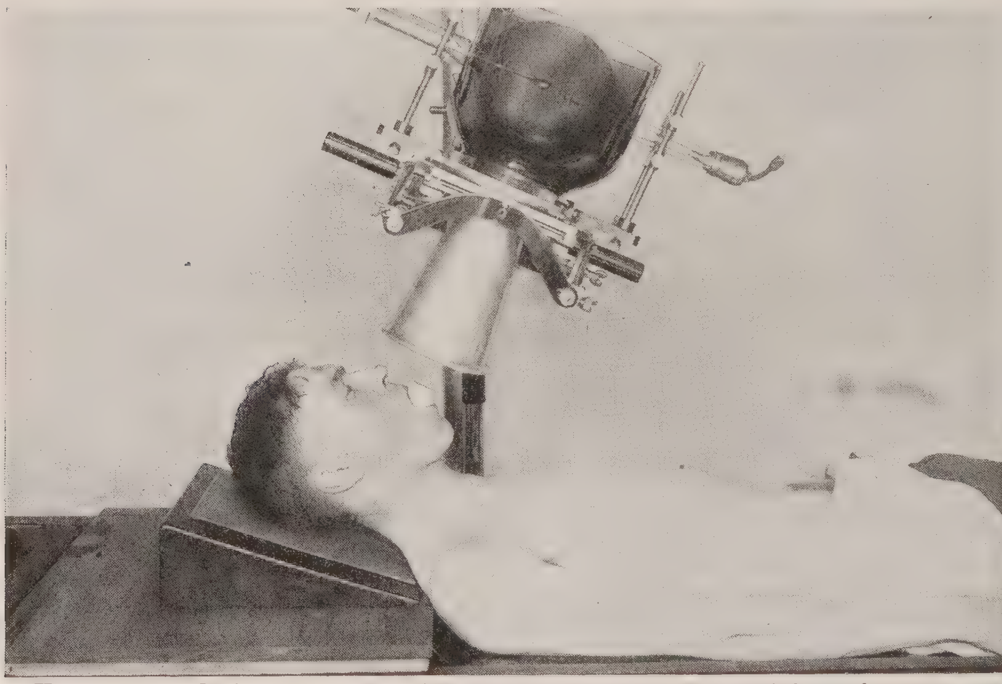


FIG. 145. Spine examination, anteroposterior position for upper cervical vertebræ.

gap, of from 3 to 5 seconds, with the usual base hospital outfit.

Lower Cervicals.—Fig. 146. The ventrodorsal projection of the lower cervicals is best obtained by supporting the plate or film beneath the patient at such an angle as to bring it in contact with the region sought. In this case, also, it will be necessary to fix the head in position to avoid hazing of the plate by movement. Exposure 40 ma., 5-inch gap, 22-inch target-plate distance, 3 to 5 seconds.

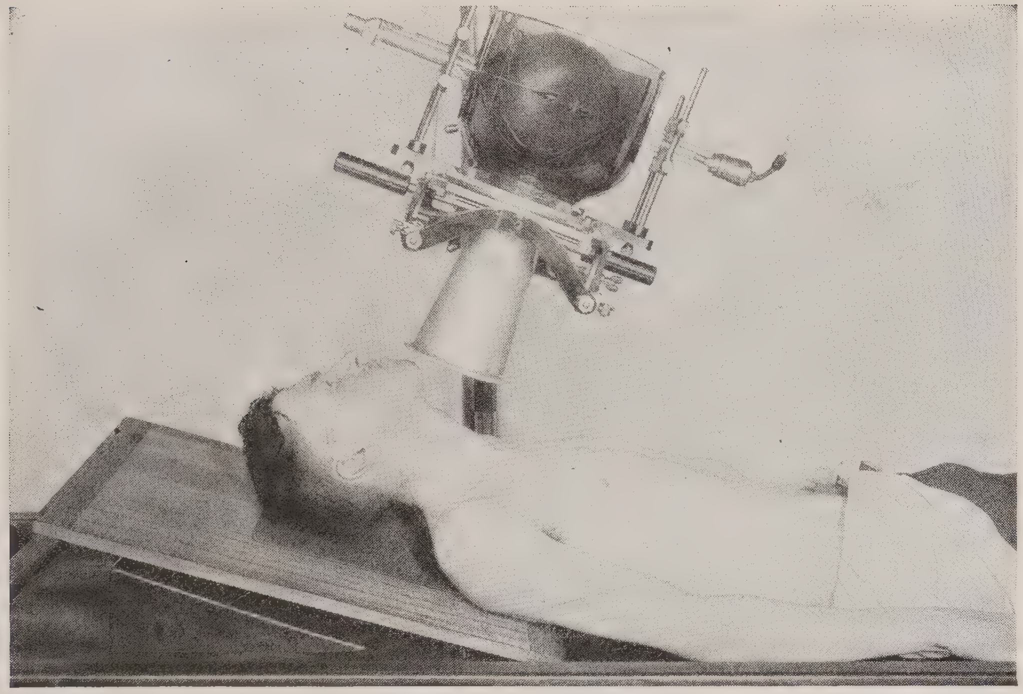


FIG. 146. Spine examination, anteroposterior position for lower cervical vertebræ.

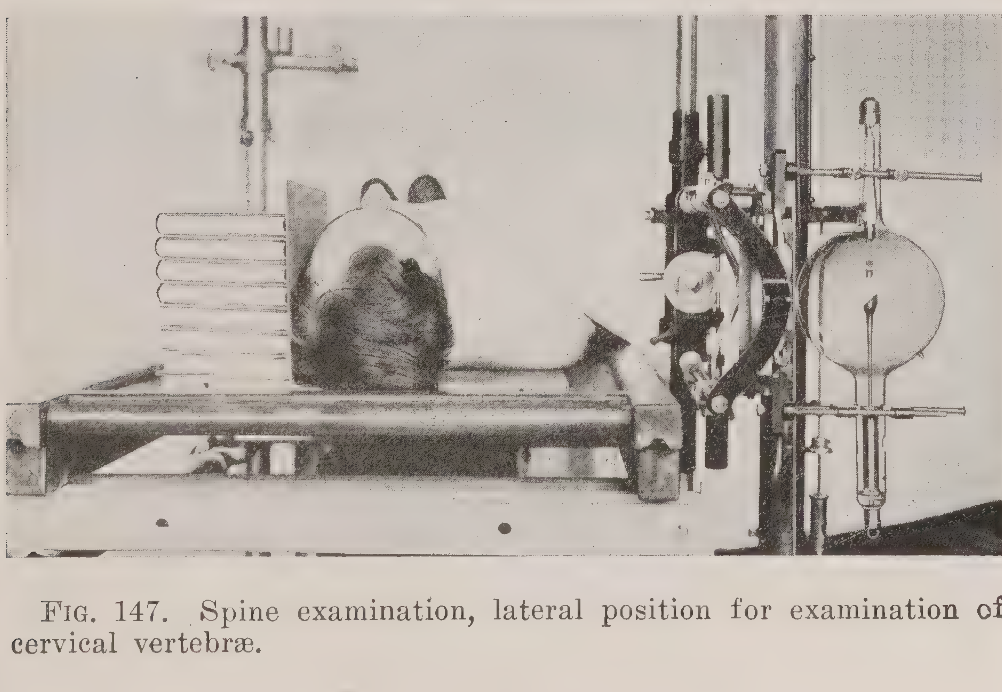


FIG. 147. Spine examination, lateral position for examination of cervical vertebræ.

If a lateral view is desired, the patient should not be turned on his side in the case of injury to the cervical vertebræ, but a plate pressed well down against the shoulder and properly supported by sand-bags or otherwise may be used. Fig. 147. For a lateral examination it is well to have the shoulders slightly elevated and to be sure that

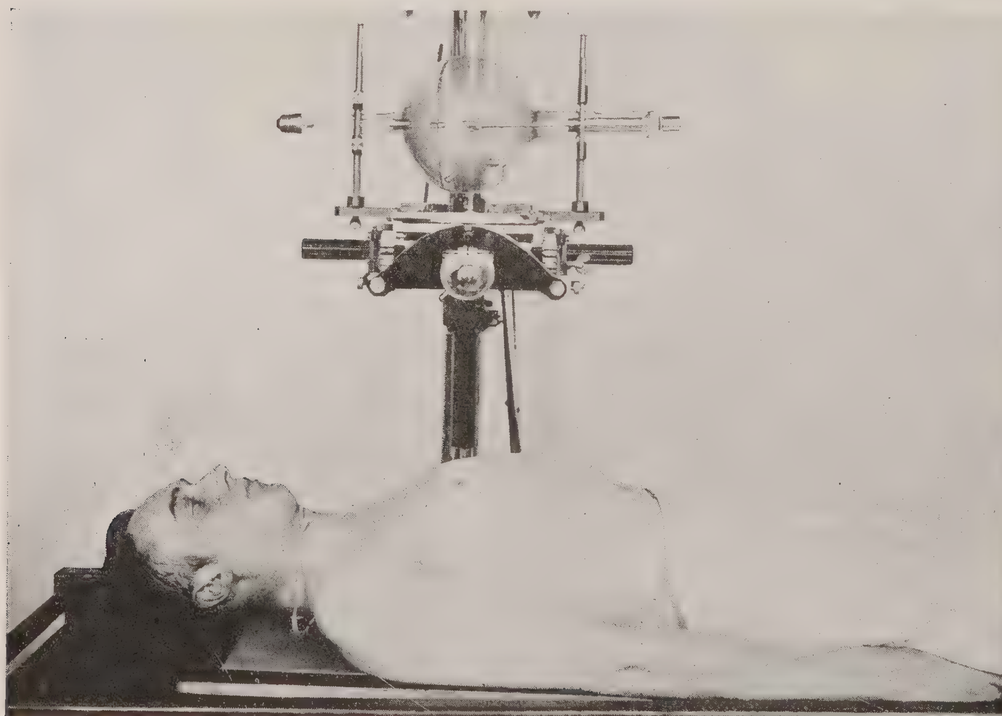


FIG. 148. Spine examination, anteroposterior position for thoracic vertebræ.

the plate covers the region sought. It may be necessary to work at 28 inches, in which case, with 40 ma. and a 5-inch gap, 5 to 7 seconds may be needed.

Thoracic Vertebræ.—The thoracic vertebræ may be taken on a large plate with a target-plate distance of 28 inches, or by the use of two small plates and two separate exposures. Fig. 148. The latter is generally more satis-

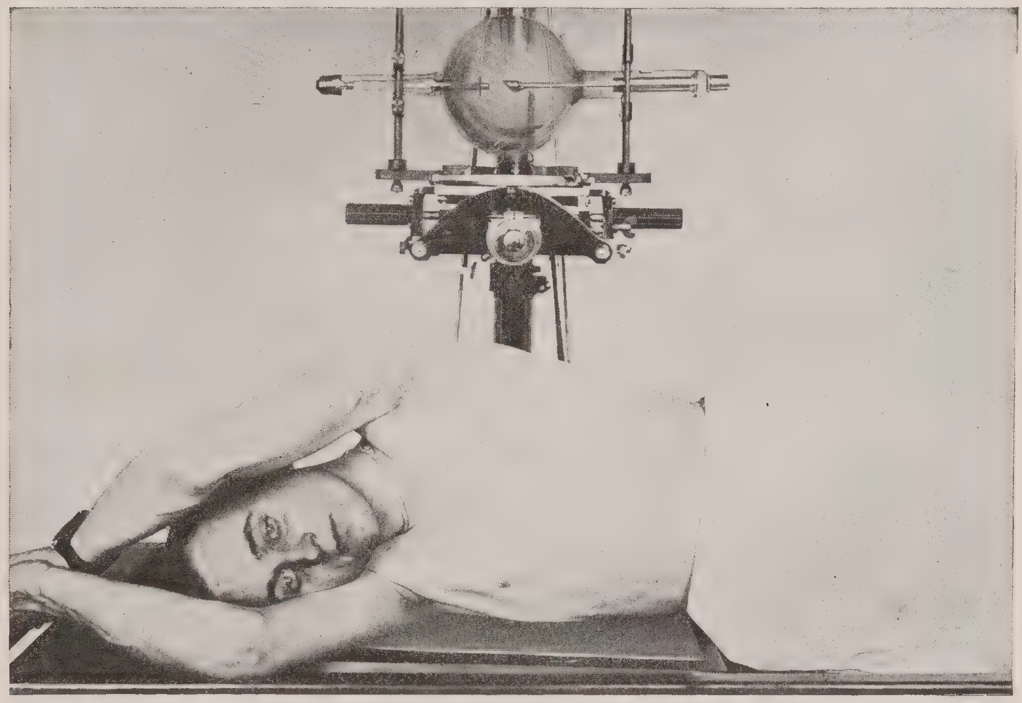


FIG. 149. Spine examination, position for lateral examination of thoracic vertebræ.

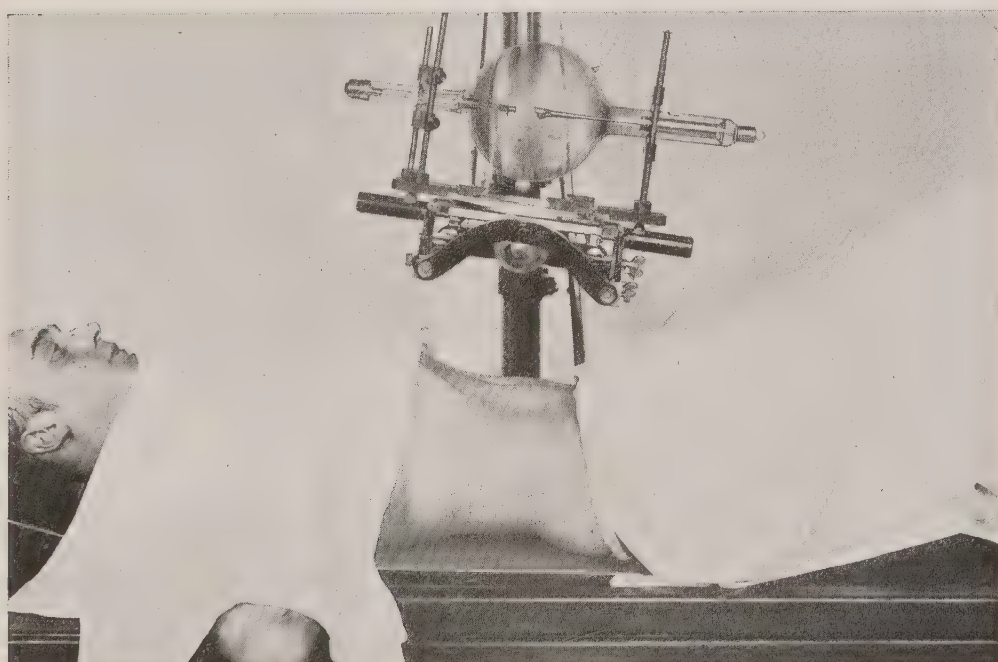


FIG. 150. Spine examination, anteroposterior position for upper lumbar region. Note flexion of knees.

factory. With 40 ma., a 5-inch gap, 28-inch target-plate distance, the time required will be from 5 to 8 seconds. The proper plate density requires careful attention, on account of the mass of superimposed material that must be penetrated.

The position for lateral examination is shown in Fig. 149, and will generally require somewhat longer exposure than the ventrodorsal, running from 6 to 10 seconds with the same current, gap and distance as before.

Upper Lumbar Region.—On account of the considerable curvature of the midlumbars special care should be taken in placing the tube and patient in order to bring out the positions of the vertebræ without overlapping. The patient should lie flat on the back and the knees should be semiflexed in order to bring the spine as close to the plate as possible. The central ray should pass through the 12th thoracic vertebra approximately, and in some cases a cone for compression will be found desirable in order to diminish the path of the rays in the body. Fig. 150. At 40 ma., 5-inch gap, 22 inches will require from 6 to 8 seconds.

Positions for other portions of the lower spine are indicated in Figs. 151 and 152 and require some practice in order to bring out the features desired. If a lateral is required of the lower spine, it will generally be desirable to use an intensifying screen, and, if this is reasonably fast, the time for the lateral exposure with the screen will not differ materially from that for the anteroposterior when no screen is used.

Abnormalities of the Spine.—Before discussing the pathological changes in the spine it is well to remember that it is the seat of more abnormalities than any other part of the bony structure. Certain of these abnormalities while not pathological in the sense of disease yet may

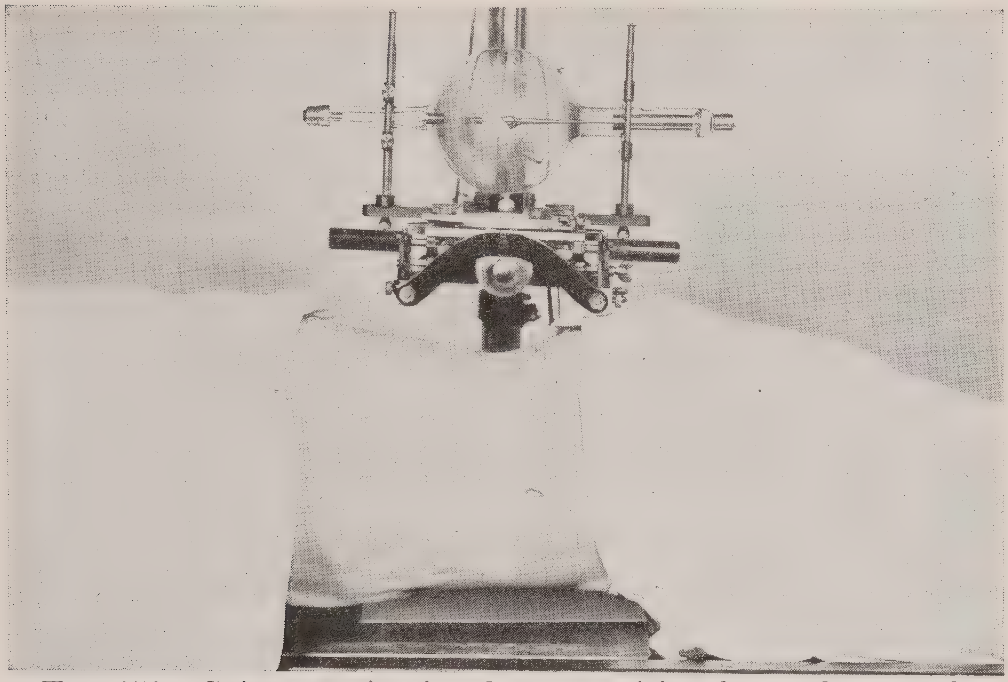


FIG. 151. Spine examination, lateral position for lumbar vertebræ.

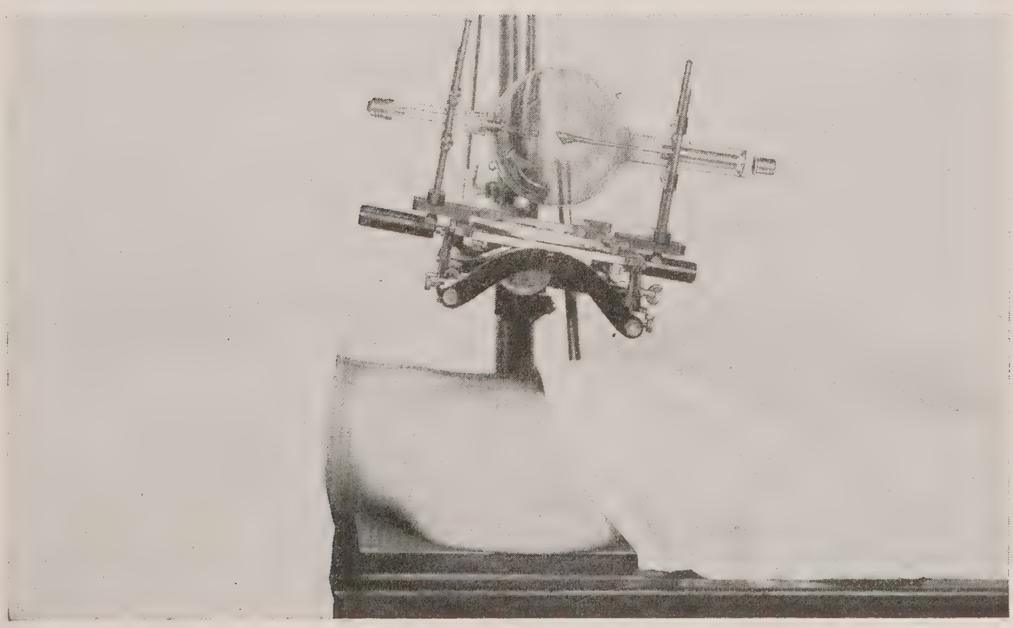


FIG. 152. Spine examination, anteroposterior position for lower lumbar vertebræ.

produce symptoms. For convenience it is well to consider them according to their locations, namely, cervical, dorsal, and lumbosacral.

In the cervical region the most common abnormality is the presence of extra ribs. They generally spring from the seventh cervical; may be either unilateral or bilateral, the former being the most common. They frequently produce pain and numbness in the arm and sometimes atrophy of certain muscles. The symptoms usually lead to a diagnosis of neuritis which, if due to pressure from one of these ribs, will not yield to medical treatment, as removal of the ribs is the only cure. When unilateral the diagnosis is easy, as one will note that the corresponding rib on the opposite side is absent. When there are two cervical ribs the diagnosis is more difficult, as they may be mistaken for the pair of normal first dorsal ribs. This can be determined only by examination of the entire dorsal spine to ascertain whether twelve or thirteen pairs of ribs are present. If there are thirteen, we know we are dealing with an extra pair of cervical ribs. The seventh cervical vertebra, from the radiological appearance, is so similar to the first dorsal that no conclusions can be drawn as to whether the ribs arise from the seventh cervical or first dorsal vertebra. The fact that there may be six cervical vertebræ does not mean that we are dealing with an extra pair of ribs, as the attachment of the ribs is variable. Sometimes they are attached one vertebra too high or one vertebra too low. It is quite common to find six cervical, twelve dorsal and six lumbar vertebræ, or eight cervical, twelve dorsal and four lumbar vertebræ.

While these extra ribs nearly always spring from the seventh cervical vertebra, it is well to remember that on very rare occasions they may be attached higher up.

Congenital nonunion of the laminæ that form the spinous processes is quite common in the seventh cervical. On account of the narrow space between the laminæ this is often mistaken for a fracture.

In the dorsal vertebræ we may also have congenital nonunion of the laminæ, generally confined to the upper two or three. Rudimentary vertebræ, triangular in shape, are sometimes seen inserted between the vertebræ. Since they are triangular in shape and inserted on one side, scoliosis invariably results. This is important, as such a condition will not yield to the ordinary treatment for scoliosis.

In the lumbosacral region nearly all of our abnormalities are confined to the fifth lumbar and sacrum. Congenital nonunion of the laminæ of the fifth lumbar and top of the sacrum is quite common. In a thousand examinations of that region for various conditions this nonunion occurred in over fifteen per cent of the cases. This is dwelt upon because the writer has seen so many cases in which this condition was diagnosed as fracture. Occasionally an extra pair of ribs may arise from the first lumbar.

Another frequent abnormality is where the fifth lumbar takes on characteristics of the sacrum—the transverse processes on one or both sides become fused with the sacrum and the fifth lumbar becomes integral therewith. When only one side is united symptoms frequently occur.

The so-called sacro-iliac subluxation or strain seems to be in reality a ligamentous rather than a bony change. In such conditions one will frequently see one side of the sacrum higher than the other, suggesting a slipping. When the patient is manipulated under anesthesia all symptoms may disappear, and second examination fails to show that the improvement has resulted from any change in the position of the sacrum.

Great care must be taken in centering the tube to secure a symmetrical position in this examination, and if conclusions are to be drawn from a second examination as regards the effect of treatment or manipulation, it is of vital importance to reproduce all the factors of position and exposure, in order that distortion may not be mistaken for real change in bony structure. It is advised that the tube be centered over the lumbosacral articulation.

While many of these cases of indefinite pain and discomfort in this region may be due to ligamentous rather than bony changes, it must be borne in mind that we do have at times a slipping of the fifth lumbar vertebra. A lateral view of the fifth lumbar and top of the sacrum may show the body of the fifth lumbar projecting anterior to the top of the sacrum.

Pathological Processes in the Spine.—In dealing with the pathological processes incident to the spine we have practically the same changes as seen in the other bones with certain modifications. For convenience of classification the writer has divided the lesions according to their origin as follows:

1. Joint lesions. Lesions arising from and involving the articulating surfaces.

2. Transitional lesions. Lesions arising from the articulating surfaces and involving the body of the vertebræ.

3. Bone lesions. Lesions arising from the body and not involving the articulating surfaces.

In class one will fall the various types of arthritis, namely, infectious, atrophic and hypertrophic, and the first stage of tuberculosis.

In class two we have the destructive stage of tuberculosis, fractures, and the neuropathic conditions such as Charcot and syringomyelia.

In class three we have the new growths and occasionally

osteomyelitis, though this may come under class two, according to whether the joint is involved or not.

Spinal Joint Lesions.—In dealing with class one, the joint infections, certain changes seen in the joints of long bones are not present, that is, we do not see any peri-articular or fluid changes, so our diagnostic points rest entirely upon the cartilaginous destruction and bone production.

In the arthritic cases, nontuberculous, we seldom see any narrowing of the joint space, but at the edges of the vertebræ, particularly where the lateral ligaments attach, the edge will first become sharpened and then exostoses will form, growing toward the joint space, and finally will unite with the exostoses from the other surface of the joint and produce a true bony ankylosis at that point. This may be so extensive that all the vertebræ will become ankylosed. There is no change in the body of the vertebræ. We cannot differentiate the various types of arthritis. In the early stages of tuberculosis we get destruction of cartilage and some narrowing of the joint, but the disease proceeds to attack the body of the vertebræ and then we get the second class, or the transitional type, where joint and body are involved.

Transitional Spinal Lesions.—In tuberculosis the anterior portion of the body of the vertebra becomes softened and then from pressure gives way, assuming a characteristic appearance, namely, the body becomes triangular in shape with the apex anterior and the base of the triangle posterior. This gives us the characteristic angulation or knuckle, the true tuberculous kyphosis. Tuberculosis is a destructive process, not a bone producer. The three important differential points to remember with this lesion are (1) angulation; (2) deformity, anterior and posterior; (3) practically no bone production.

In fracture and dislocation of the spine, and they are generally present together, we have destruction of the joint and more or less crushing of the vertebræ. The displacement is lateral and soon there is marked new bone formation. The three important differential points are (1) angulation; (2) deformity, lateral; (3) new formation of bone.

The above applies only to the dorsolumbar region. In the cervical region in fracture and dislocation, the displacement is frequently anteroposterior instead of lateral, though both may occur. Besides the fracture-dislocation of the bodies proper, fracture of the transverse processes in the lumbar region is quite common. These not only follow from injury but from violent strains. They are generally easily recognized, as there is always more or less separation of the fragments and the outer end is frequently displaced upward.

In the neuropathic conditions, namely, Charcot, there is always the lateral crushing of the joint, and the body is involved with the formation of bony detritus, seldom new bone formation. The three differential points are (1) angulation; (2) deformity, lateral; (3) seldom new bone formation, but generally bony detritus present.

Spinal Bone Lesions.—The most common lesions are the new growths, and the same system of differentiation applies here as in growths of the long bones. When the growth arises from the edge of the vertebra and there is bone production outside, the condition may simulate fracture and dislocation, but the striking point is that in growths the joint is not involved.

In sarcoma and carcinoma a portion of the vertebra may be completely absorbed, but, on account of the density of the growth, crushing of the body takes place slowly and

equally. The body will become narrowed, but the joint spaces will be intact and clearly seen.

A vertebra that is much smaller in width with joint spaces intact should always be viewed with the possibility of growth in mind. The characteristic points are (1) no angulation; (2) no displacement; (3) narrowing of body with or without bone production, according to type of tumor.

Osteomyelitis is uncommon, though the writer has seen one case of typhoid origin involving both the joint and body. The changes observed were the same as seen in osteomyelitis of the long bones.

Lesions of the Long Bones.—In discussing the pathological lesions that take place in bones we must remember that we have three normal constituents to deal with, namely, the medullary canal and its contents, the cortex, and the periosteum. From an x-ray standpoint there are only two pathological changes that take place, namely, bone destruction and bone production. It matters not what the nature of the lesion is, one or both of these processes are present. It is only by a careful analysis of the character of the destruction and the character of the bone production that we are enabled to differentiate these lesions. The most important thing to determine is whether we are dealing with a malignant or a benign condition. If that point can be determined, we have given the surgeon or clinician all the information that is necessary. It is, however, better if we can go further and determine the exact nature of the lesion.

In taking up the subject of tumors of bone there are certain well-known manifestations which are fairly characteristic of certain lesions. By studying the point of origin and the character of the bone changes we have been led to formulate a rough scheme for the analysis of these

various bone tumors. We have taken as a basis four cardinal points which are as follows: origin of the tumor; presence or absence of bone production; the condition of the cortex; and, finally, invasion. At first glance it is often impossible to determine all four of these points, but, if we can establish one or two of them, they frequently lead to the correct diagnosis.

Discussing these four points, the salient features are as follows:

Point of Origin.—By that we mean whether the growth arises in the medullary canal or springs from the cortex or periosteum. If this point can be determined we have established one point of differential diagnosis. All tumors in bone must be either primary or metastatic. We know, for example, since there is no epithelial tissue in bone, that if we have a carcinoma it must enter the bone by means of the lymph vessel with the nutrient artery, and, consequently, the growth must start in the medullary cavity. Therefore, if we can establish the point that the growth does not arise in the medullary cavity, we have ruled out carcinoma. On the other hand, since sarcoma is of connective-tissue origin it can be either primary in the medullary canal or of metastatic origin. We know, too, that enchondromata and bone cysts may also arise from the medullary cavity, so we have to proceed to the other cardinal points to establish a differential diagnosis.

Bone Production.—Bone production cannot take place in either carcinoma or in the round-cell, spindle-cell and giant-cell sarcomata. Consequently, if we can establish the point that there is bone production within the tumor, the above-mentioned tumors can be ruled out. That, in turn, will again limit the tumors to osteoma, osteochondroma, periosteal sarcoma, osteosarcoma, and ossifying

hematoma—the latter arising beneath the periosteum is very frequently mistaken for a malignant growth.

Cortex.—For further differentiation we have to proceed to the third cardinal point, namely, the cortex. We must determine whether the cortex is present or absent, and, if present, whether it is expanded in a spherical or longitudinal manner. Secondly, we must determine whether the growth springs from the cortex or periosteum. If we can definitely establish that a growth springs from the cortex or periosteum it must be a bone-producing tumor, and the character of the bone production will definitely aid us in determining the nature of the tumor.

The condition of the cortex is also a very important factor. Experience has shown us that benign tumors arising in the medullary canal always take the path of least resistance, that is, they have a tendency to grow up and down the shaft in the medullary canal rather than towards the cortex of the bone. The pressure from the growth, however, causes an expansion of the cortex, but the expansion is always spindle-shaped or cylindrical and the cortex is always intact. On the other hand, in malignant conditions the growth is always spherical in nature and extends equally in all directions. The cortex does not offer any interference, and the growth sweeps through and destroys it, so that in this character of growth the cortex is absent, and if a trace of it remains it has not been expanded. There is only one exception to this, and that is the giant-cell sarcoma. As its name implies, it belongs to the sarcomatous group, but, on account of the character of the cell, metastasis is almost impossible, so that we are dealing with practically a benign condition. It is a very slow growing tumor, but it grows in a spherical manner, and on account of its slow growth the cortex is expanded in all directions

but is not destroyed. The growth, too, is definitely limited in the medullary canal.

Invasion.—The fourth point, invasion, is frequently the hardest to determine. If, however, it can be determined, it is the most important of all points. If we can establish definitely that the growth is invasive, by that meaning infiltration into bone and soft tissue, we have in reality determined everything, because *malignancy depends upon invasion.*

After determining these four points it is well then to take up what might be termed the laws of probabilities. By these laws we mean what is most frequently found when the age and the sex of the patient are taken into consideration, and what particular bone is involved. As an example, if the patient is a female, statistics show that carcinomata of the breast and of the pelvic organs are by far the most common. We also know that in carcinomata of the breast metastases occur most frequently in the greater trochanter, the spine, ribs, humeri and the ilia. In carcinoma of the pelvic organs the metastases are generally in the lumbar spine. In the male we know that carcinomata of the lip and tongue and of the genito-urinary organs are most common. With the lip and tongue, if metastases do occur, they take place chiefly in the mandible. In carcinomata of the genito-urinary organs, particularly the prostate, the metastases occur in the pelvis and lumbar spine. Thus we see that knowledge of the sex of the patient is frequently an important aid to diagnosis.

A second application of the law of probabilities, namely, the age of the patient, helps us very materially. In the first place, since carcinoma of the bone is a metastatic condition we must always look elsewhere for the primary growth. Then, too, experience has taught us that carcinoma is unusual in the young individual, but is essentially a disease of middle and old age. On the other hand, sar-

coma may occur at any age. In diagnosing a tumor in a young individual, the law of probabilities indicates that it is more likely to be a sarcoma than carcinoma; in an old individual it may be either a sarcoma or a carcinoma.

The particular bone involved when sarcoma is present does not help us because sarcoma may be primary in the bone and, consequently, can form in any bone. The following are the chief characteristics of the more common bone tumors:

Specific Lesions.—*Carcinoma* is always medullary in origin and, since it enters by means of the lymph vessels, it must enter the bone with the nutrient artery, that is, at its middle point. Consequently, we may say by the law of probabilities that carcinoma is more apt to be situated in the region where the nutrient artery enters. Since it is epithelial in origin, there is no bone production within the tumor; it grows equally in all directions, does not expand the cortex but destroys it completely, and shows distinct signs of invasion down in the medullary cavity and soft tissues. This tumor occurs in middle and old age.

Round-cell sarcoma is also very malignant and its characteristics are identically the same as those of carcinoma. As far as the growth is concerned it cannot be differentiated from carcinoma upon the x-ray plate. In such a growth, to make a differential diagnosis between it and carcinoma, we must again refer to the law of probabilities, namely, sex, age and bones involved. Its situation in the bone itself is of some significance because, while sarcoma may occur in any part of the bone, carcinoma is most frequent near the nutrient artery; so a tumor at the end of bones, by the law of probabilities, is more apt to be a sarcoma than carcinoma.

Spindle-cell sarcoma while malignant is not as much so

as round-cell sarcoma. It also destroys equally in all directions; does not produce any bone; destroys the cortex, does not expand it; but the growth does not show the same degree of invasion in the medullary canal as the more malignant round-cell sarcoma.

Periosteal sarcoma, as its name implies, arises from the periosteum. It produces bone, but the major portion of the bone is laid down in the soft tissues. The shaft of the bone shows but very little destruction. This tumor is so malignant that death ensues before the growth has destroyed the bone to any extent, as most of its growth extends into the soft tissues. The bony production is very typical and characteristic, namely, it is laid down in long striæ and is invariably perpendicular to the shaft.

Osteosarcoma arises from the cortex of the bone. It is frequently impossible to determine whether it arises from the medullary canal or not. If the growth should start on the inner surface of the cortex next to the medullary canal, since it grows equally in all directions, one might think that it arose from the medullary canal. So the point of origin in some of these cases does not help us, but the fact that there is bone production within the growth is of great significance. The shaft of the bone is somewhat destroyed and there is new bone production, not only within the shaft but, like the periosteal sarcoma, within the soft tissues. This bone, like the periosteal sarcoma, is laid down perpendicular to the shaft, and in osteosarcoma there is generally more bone production than in the periosteal type. The sarcomata may occur at any age. The fact that in both of these malignant conditions the bone is laid down perpendicularly to the shaft is of special significance and will be discussed a little later.

The metastases in *prostatic carcinoma* give the same x-ray signs as the other forms of carcinoma with this ex-

ception. Since this type of tumor grows very slowly we find production of new bone not within the growth but just at the edge of the growth in the normal bone, in other words, at the point of stimulation. Consequently, this growth seems to be encapsulated in a calcium wall, nature attempting to limit the growth. These metastases are most commonly seen in the pelvic bones, sacrum and lower lumbar vertebræ; and in people of middle or old age.

Giant-cell sarcoma develops from the medullary portion of the bone and expands equally in all directions, similar to a malignant growth. It is, however, definitely limited; the cortex is expanded but intact. There is no new bone formation. It is generally seen between the ages of twenty and thirty. The growth is usually situated at the end of the bone, and the radius and tibia seem to be the bones most commonly involved.

Enchondroma, as its name implies, is cartilaginous in origin and is generally seen before the epiphyses have united. The early recognition is probably due to the fact that fractures take place through this growth quite readily; the patient comes in for the fracture and the tumor is then discovered. The growth is situated near the ends of the bones in the region of the epiphyseal line, seldom extending beyond this line into the epiphysis proper. It is generally multiple and the growth is cystic in character—one growth may contain several cystlike formations. It extends up and down the shaft; the cortex is expanded in a spindle-shaped manner but intact. There is no new bone formation unless there has been an injury. It may arise either from the medullary portion or the cortex. Any of the long bones in the body may be involved, the phalanges of the hands being probably the most common. These usually occur between the ages of seven and fifteen years.

A *cyst* is seen most commonly in the same ages as the

enchondroma and, like it, occurs at the ends of the bones in the region of the epiphyseal line. It extends up and down the shaft; the cortex is expanded in a spindle shape; the cyst may be lobulated, but is generally one large single cavity; the cortex is intact and the walls of the cyst are sharply defined. Cysts are supposed to be multiple, but in a great number of cases observed by the writer no case of multiple cysts was found. Cysts are generally medullary in origin and occasionally, but rarely, may spring from the cortex.

Osteoma arises from the cortex and, as its name implies, is a dense bony tumor. The growth extends out into the soft tissues, the bone being laid down very symmetrically, and has the typical cauliflower appearance. It is frequently lobulated, has a very definite outline, and no sign of invasion. These growths are generally multiple at the point of origin, are seen most commonly in the young, and are generally perpendicular to the shaft. The bone in these growths is much denser than the shaft and does not have the same bony structure. Exostoses are sometimes mistaken for small osteomata. Exostoses, however, have the same character of bone formation as the shaft; they spring from the shaft at an angle and always point away from the nearest epiphysis. Occasionally one may see such an exostosis with an osteoma forming at the tip. The most common situation for osteomata is around the shoulder and in the neighborhood of the knee joint.

Ossifying hematomata, while quite common, are at the same time often mistaken for malignant growths clinically. The x-ray appearance, however, is quite different. This lesion is caused by some trauma to the periosteum which causes the formation of a hemorrhage beneath the periosteum and it, in turn, is raised up by the hemorrhage. When this first takes place the x-ray appearance does not help

us, as it reveals nothing, but at the end of about three weeks the periosteum will lay down new bone and the hemorrhage beneath it will undergo organization with a deposition of calcium salts. The calcium salts, however, are laid down parallel to the bone, and the periosteum, of course, makes a definite border to the growth. In adult life this is most commonly seen in the thigh; in children it may occur in any bone but only in connection with scurvy.

Special attention must be given to the way in which the new bone is laid down in this condition. We have already spoken of four conditions in which bone has apparently been thrown down in the soft tissues: two malignant conditions, periosteal sarcoma and osteosarcoma; two benign conditions, osteoma and ossifying hematoma. The important differential point is that in malignant conditions the bone is laid down perpendicular to the shaft and in benign conditions it is laid down parallel to the shaft.

Osteitis fibrosa cystica is occasionally seen and can easily be classified as a benign condition by the fact that the bone has become softened and deformities have resulted, particularly around the head of the femur. The shaft is expanded cylindrically, the cortex is intact and the bone itself is frequently filled with multiple cystlike formations. It generally occurs in the young adult.

Paget's disease is sometimes mistaken for osteomyelitis. It is seen in the long bones, particularly the tibia and femur, and the cranial bones are also affected. The long bones may be somewhat bowed, there are long longitudinal striæ of absorption present and longitudinal areas of increased calcium salts. The cortex in places may be thickened. The changes in the cranial bones, however, are most characteristic. The head seems to be enlarged, and the x-ray appearance shows that the parietal, frontal and occipital bones are very much thickened by knobbylike deposits

of bone. In acromegaly the cranial bones are very much thickened; the head seems to be elongated anteroposteriorly and the lower jaw projects markedly forward. The sella turcica is frequently enlarged and deepened. The bones and soft tissues of the hands and feet are very much enlarged, and the tufting of the terminal phalanges is materially increased.

Brain Tumors.—In speaking of the changes in the cranial bones it is well to mention in this connection some of the characteristic signs of brain tumors. Unfortunately, the x-ray evidence for these tumors is not particularly reliable, as a vast majority of brain tumors are of the same consistency as the brain itself and, consequently, there can be no differentiation between the tumor and the brain. We have to depend entirely upon other signs, and, unfortunately, they are late manifestations of the tumor, namely, erosion of the bone, due to pressure, and engorgement of the vessels—these vessels having a tendency to center at one point, that is, in the growth. This indirect evidence, however, cannot always be relied upon. In tumors of the hypophysis the signs of pressure appear earlier. Since this gland is closely confined in the sella turcica the pressure symptoms, such as erosion and distortion of the bone, appear early.

Osteomyelitis.—Care must be taken not to confuse inflammatory growths of bone with tumors. This is particularly true in osteomyelitis. This disease gives no definite x-ray signs during the early stages (first ten days). Later we find destruction within the bone with the formation of sequestra, and the disease extends down the shaft in an irregular manner, but the shaft is never expanded. The periosteum may lay down new bone which may give the appearance of expansion, but upon looking at the plate closely we will see that the apparent expan-

sion is due to the deposition of bone on the outside. When the disease breaks through the cortex it does so in one or two places only and does not destroy the cortex as a whole, as the malignant tumors do. It is sometimes quite difficult to differentiate between simple osteomyelitis and that occasioned by lues. It is well to bear in mind that when we have, apparently, an extensive osteomyelitis of the bone, very little swelling of the soft tissues, and very few clinical signs, the condition is more apt to be luetic in origin, as the acute simple inflammatory osteomyelitis is generally accompanied by marked clinical signs and marked soft tissue swelling, redness and fever.

Periostitis may be a simple inflammatory lesion or luetic in origin. It is sometimes very difficult to differentiate these two conditions. The simple inflammatory periostitis lays down the periosteal bone parallel to the shaft. Luetic periostitis also generally lays down bone parallel to the shaft, but occasionally the new periosteal bone may be laid down perpendicular to the shaft very similar to that seen in certain bony malignancies. In the luetic periostitis, however, the amount of bone is small and closely confined to the shaft, not extending out into the soft tissues, so that a mistake can probably seldom arise. In luetic periostitis more than one bone is frequently involved, while the simple inflammatory type generally affects only one bone.

The cardinal points which have just been given for bone lesions hold only for the long bones and not for the flat bones, as in the flat bones the growth is so frequently atypical. A second important point to remember is, that, if there has been any surgical interference, no conclusions can be drawn from the x-ray standpoint, because the diagnosis depends upon bone destruction and bone production. If there has been trauma or surgical interference the new bone production may be due entirely to the

two latter conditions. Consequently, we may draw false conclusions, since these changes are not due to the tumor itself.

Tuberculosis of the joints with direct extension of the disease into the heads of the bone forming the joint has been taken up in the section on arthritis. Tuberculosis of the long bones without the joint involvement is so extremely rare that it does not come within the scope of this manual.

Below is a summary of the bone tumors according to the four cardinal points:

1. Origin-Medullary.
   - Sarcoma
   - Carcinoma
   - Bone cysts
   - Enchondroma
   - Giant-cell sarcoma
2. Cortical.
   - Periosteal sarcoma
   - Osteosarcoma
   - Osteoma
   - Enchondroma
   - Ossifying hematoma
   - Occasionally bone cysts
3. Bone Production.
   - Periosteal sarcoma
   - Osteosarcoma
   - Osteoma
   - Ossifying hematoma
   - Enchondroma and bone cysts (when there has been trauma)
4. Cortex not expanded but destroyed.
   - Sarcoma

Carcinoma
Osteosarcoma
Periosteal sarcoma

5. Cortex expanded and intact.
   Enchondroma
   Bone cysts
   Giant-cell sarcoma
6. Invasion.
   All of the malignant tumors show invasion.

Arthritis.—A normal joint is composed of three parts, namely, cartilage, synovial membrane and the synovial fluid. There is no free bone in the joint proper; the consequence is that in attempting diagnosis of joint conditions we do so by means of the changes in one or more of these three parts.

We may divide arthritic conditions into two classes. First, the acute, and, second, that large group which we may class as arthritis deformans. Under the first group would come the acute polyarticular rheumatism. This type comes nearer to being a distinct clinical entity than any of the other forms of this disease.

The object of this article is not to deal with the clinical symptoms but with the x-ray findings; consequently, we will confine ourselves entirely to the changes that can be seen upon a plate.

In acute polyarticular arthritis the x-ray indications are rather indefinite. We find that there is an increased amount of fluid in the joint, and the synovial membrane and periarticular tissues are swollen. There is no destruction of cartilage, as we can tell by the fact that the joint space is of normal width. The cartilage itself is not visible by means of the x-ray, so we have to judge its presence or absence by indirect evidence, namely, the width

between the bony surfaces that compose the joint. Since, in this condition, there is no destruction of cartilage we may expect the joint to come back to its normal condition, and, after the disease has subsided, the x-ray examination will show an absolutely normal joint.

When we take up conditions in rheumatoid affections we meet very considerable difficulties. The classifications of the various types under this head are very unsatisfactory, and then, too, these so-called chronic rheumatisms have so many names for the same condition. For example, we see the terms chronic rheumatism, arthritis deformans, rheumatoid arthritis, osteoarthritis and spondylitis used indiscriminately by different individuals and yet meaning the same condition. There is no classification which is absolutely satisfactory, but that adopted by Goldthwaite many years ago is, taken as a whole, probably the best. Of course, many men take exception to his classification and do not agree with it as a whole, but its simplicity and the great number of cases which can be classified according to it makes it seem generally the most useful. He divides the chronic arthritis into:

1. The infectious type. This includes tuberculosis, gonorrhea, syphilis, pneumococcic infection and those types of arthritis which have the same clinical manifestations, but where the etiological factor is unknown.
2. Those cases designated as atrophic.
3. The hypertrophic cases.

Infectious arthritis, from an x-ray standpoint, presents three different appearances, according to the stage of the disease at the time of examination. For example, in the first stage we have an acutely inflamed joint, and a marked amount of fluid present with periarticular swelling. There is no cartilaginous destruction and consequently no bone destruction. This stage gives the same x-ray appearance

as an acute polyarticular rheumatism or an injury to the joint without fracture, because in these conditions we also get fluid, periarticular swelling and no cartilaginous changes. In the second stage the disease probably reaches its maximum intensity and, in time, the following changes take place in the joint and bone. In the first place, on account of the disuse of the joint, we begin to get a generalized atrophy of the bone, the swelling has partially disappeared and the fluid may be partially absorbed. The cartilage is now eroded, as shown by the fact that the joint space is narrowed, but there is no new bone formation. The soft tissues may have even atrophied somewhat. Occasionally we may see punched-out areas extending through the cartilage down into the bone. In the third stage, or we may term it the stage of repair, the active infection has disappeared and the patient is beginning to use the joint, consequently, the atrophy is disappearing or will have completely disappeared. The soft tissues are resuming their normal appearance, and, where the cartilage has been destroyed, it is replaced by proliferation of new bone. In other words, we get the formation of bony exostoses. The extent of these exostoses depends entirely upon the severity of the lesion, and in some cases cartilage has been so completely destroyed that we have a true bony ankylosis. This type of infection is seen in all ages of life, that is, from early adult life up to and through old age.

Atrophic Arthritis.—Atrophic arthritis is generally seen in early middle age. There is marked atrophy of both soft tissues and bone. The joints are frequently partially subluxated, due to the contraction of the tendons, and there is limitation of motion; the latter is not due to bony ankylosis, however, but to fibrous changes and muscle contracture. The x-ray examination shows marked atrophy of the bone. There is extensive absorption of cartilage

and its complete destruction in certain areas, but there is apparently no attempt at new bone formation. From this description one can readily see that the atropic arthritis simulates very closely the second stage of infectious arthritis. The only differential point is that at no stage in this disease is there any fluid or periarticular swelling, while in the second stage of infectious arthritis one is apt to find a small remaining amount of swelling and fluid. Many clinicians think that atrophic arthritis is not a distinct clinical entity but probably one of the stages in an infectious arthritis.

Hypertrophic Arthritis.—Hypertrophic arthritis is a disease almost invariably associated with people of middle life and old age. One rarely sees this type under thirty-five and it is most pronounced in patients in the neighborhood of fifty and over. The x-ray examination shows that there is practically no atrophy, in fact, there is condensation of bone so that the bone shadows are even a little denser than normal. When the age of forty-five is reached there is always a certain amount of atrophy in the bone, due to what might be called a senile change. This is completely absent in the hypertrophic type. Besides the condensation of bone there is a marked formation of exostoses, due to small areas of cartilaginous destruction and marked lipping at the edge of the articulating surfaces. Frequently little, bony, loose bodies may be present in the joint (joint mice). There may be ankylosis of the joint, but this is not a true bony ankylosis but simply one due to the mechanical locking of these bony exostoses. This type simulates the third stage or the stage of repair in an infectious arthritis. In hypertrophic arthritis, if the condensation of bone is absent, it is extremely difficult and, at times, impossible to differentiate between the third stage

of infectious arthritis and hypertrophic arthritis, particularly if the patient is in the neighborhood of fifty.

Great care must be taken not to confuse the slight arthritic changes which are always present in people over fifty with an acute active process. It has been definitely established that practically all of us when we reach the age of forty-five show small exostoses in and around the joints, and yet there may be no clinical manifestations of an arthritic process. It is particularly in these joints that we get such marked symptoms following a slight injury—symptoms out of proportion to the extent of the injury. In this condition we must remember that the injury has simply lowered the resistance of the joint and has allowed this quiescent arthritis to flare up into an active process, so that the marked clinical manifestations seen in such joints are really the result of the arthritis and not of the trauma.

We have mentioned the subdivisions under infectious arthritis where the etiological factor is known. The question naturally arises, do any of these give such definite x-ray changes that we can actually determine the specific type of the infection with which we are dealing. Unfortunately, the majority of them give the same x-ray indication. Some, however, give fairly constant appearances so that they can be readily recognized.

In *tuberculosis of the joint* we have a marked hazing so that the x-ray shadows are very indistinct. In fact, it suggests that we have a very poor plate, but in this same plate one will note that the bones adjacent to the affected joint come out sharply and distinctly. It is only the joint itself that is hazy and indistinct. This is due entirely to the thickening of the synovial membrane. Upon close inspection we will find that the bone contour, that is, the bone beneath the cartilage, is very indistinct, irregular and

eaten out. In the active process fluid is present and there is marked periarticular thickening. When the disease subsides this haziness and indistinctness of the joint disappears, but we still have an irregular and eroded joint surface, indicating that there has been some destruction of cartilage and slight destruction of the bone beneath. There is very little tendency to new bone formation, and the ankylosis, if present, is generally fibrous in nature. Since these joints when untreated so frequently form sinuses, there is a great chance of having another infection besides the tuberculosis in the joint. It is in these mixed infections that we see the marked new bone formation.

Gonorrheal arthritis does not give us distinct x-ray appearances. It varies according to the severity of the lesion. In only one joint do we have fairly definite characteristics, namely, the knee joint. In that particular joint, for some reason, the greatest severity of the lesion seems to take place in the cartilages beneath the patella, and early bony ankylosis occurs. In a knee joint in which we find ankylosis between the patella and the femur gonorrheal arthritis must be borne in mind. Exostoses and ankylosis are quite common in this disease.

Syphilitic arthritis shows marked periarticular swelling, thickening of the synovial membrane and fluid in the joint. This type does not go on to cartilaginous destruction, consequently, when the disease subsides we have a perfectly normal joint. The x-ray appearance is identically the same as that of an acute polyarticular rheumatism. Fortunately, this type is generally accompanied by bone change. While this change is not present in the joint itself at the same time it is fairly characteristic, namely, a small area of periostitis forming just at the point where the cartilage of the joint ceases and the periosteum of the bone begins. This periostitis in conjunction with periarticular swelling

and fluid in the joint is fairly characteristic of a syphilitic lesion.

The *Charcot joint* must not be confused with this acute syphilitic joint, since the changes in the former are neuropathic rather than infectious and are characterized by great destruction of the joint with splitting off of large fragments of bone, which lie free in a swollen joint filled more or less with fluid. In addition, there is marked eburnation of the remaining ends of the bones. Upon glancing at such a joint one is struck by the marked degree of disorganization that it has undergone and instinctively feels that such a joint could not possibly be used. On the other hand, there is absolutely no atrophy of the bones, indicating that the joint has not been at rest. Joints which undergo any degree of disorganization are always extremely painful and remain at rest. They consequently show marked atrophy, so that when one sees a markedly disorganized joint without any atrophy of the bone at all one should seriously consider the possibility that the condition is not an ordinary infection but a Charcot joint.

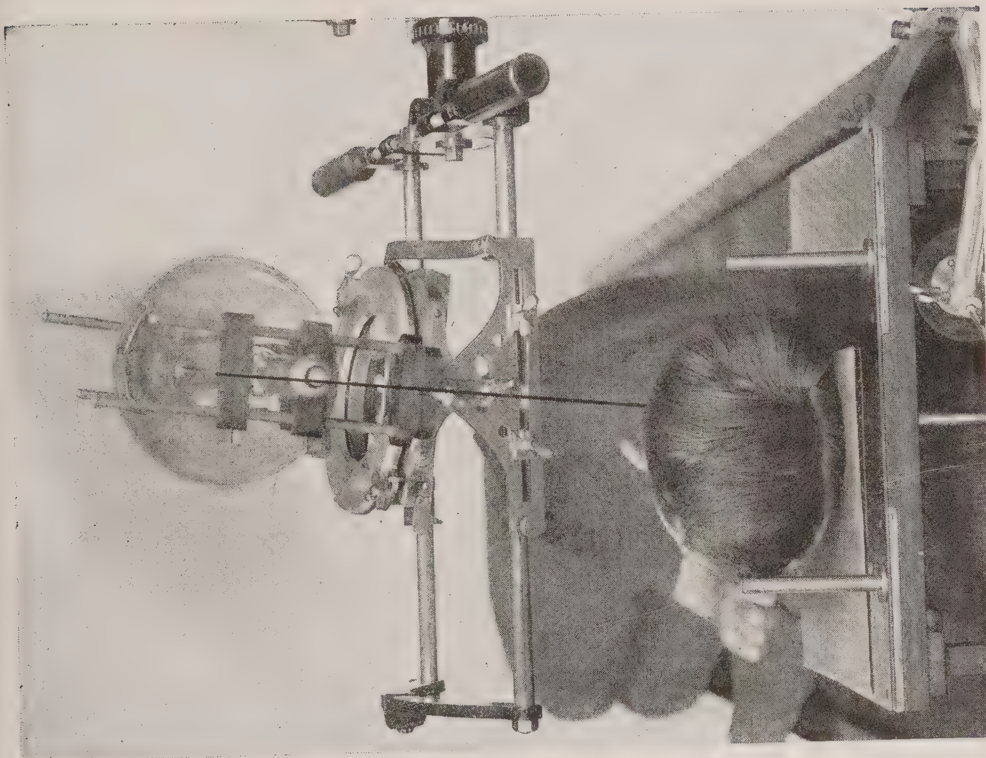
Occasionally, but not frequently, one runs across a joint giving the clinical symptoms of an infectious arthritis, but the x-ray examination shows a rather remarkable condition. There is marked destruction of the cartilage of the joint, slight new bone formation, and a hazy joint, simulating tuberculosis; but in the joint cavity itself there is a blood clot which has undergone either fibrous or bony change. When such a condition is present it is invariably the result of hemophilia.

The remaining forms of infectious arthritis do not give any definite x-ray appearances. The object of this chapter is to give a rough classification. In joint diseases, as in other conditions, the clinical aspect of the case must be taken into consideration in order to arrive at a diagnosis.

SINUSES AND MASTOIDS

Technique for Mastoids.—It is necessary to make an examination of both mastoids. This may be done on one 8 by 10 plate, by covering one-half of the plate with a thick piece of lead and making one exposure on the uncovered portion, then changing the lead cover to the exposed side and making the second exposure on the side which had previously been covered. It is necessary to compare one mastoid with the other, and placing both on the one plate makes comparison of the two sides much easier than if separate plates are made.

The patient lies on a table with the head on a small raised platform, the affected ear next to the plate with the pinna folded forward. There should be a clamp on the platform with adjustable pads to press on the occiput and forehead, but not so as to obstruct a clear view of the mastoid cells. The head is placed so that the sagittal plane will be parallel to the plate. The tube is centered over the head in such a way as to direct the central ray downwards and forwards toward the opposite ear. An angle of fifteen degrees from behind forward towards the face and fifteen degrees from above downward towards the feet will in the majority of cases be correct. In case the shape of the head is such that the sagittal plane cannot be placed parallel with the plate, without raising the mastoid area above the plate, the angle of the tube must be altered to accommodate it. The central ray should enter the head above and behind the external auditory canal, and emerge at the external auditory meatus next to the plate.



FIGS. 153 and 154. Position for mastoid examination, head resting on side of affected ear, central ray entering head at angle of 15° toward face and 15° toward feet.

The tube stand should be supplied with a small cone and this brought down with firm pressure on the head. Stereoscopic plates may be made by shifting and tilting the proper distance on each side of the angle. Figs. 153 and 154.

Technique for Accessory Sinuses.—In order to obtain a satisfactory postero-anterior image of all the accessory sinuses at one exposure, it is necessary that the rays pass through the head at a certain angle. If this angle is not observed, the petrous portion of the temporal bone obstructs the view of the ethmoids or antrum, or the sinuses are so distorted that the information given is not correct.

The proper angle is one which will cause the shadow of the petrous portion to cut across the lower one-third of the orbit and upper one-third of the antrum, leaving the lower two-thirds of the antrum free and also the upper two-thirds of the orbit clear. Fig. 155. The superior portion of the antrum is not so important, as any condition affecting the antrum to the extent of an x-ray diagnosis will involve the inferior portion as well. The possible exception to this is in the case of a fracture involving the lower orbital margin. In this case the petrous portion must be thrown down into the antrum, or a plate must be made in the vertical position.

The position described shows clearly all that is required of the frontals, ethmoids, and antra on a single plate, and the sinuses in their proper relation and size.

To obtain this position the principal ray must be directed through the head at an angle of twenty-three degrees from a line extending from the external auditory meatus to the glabella.

This angle may be obtained by a pair of dividers or a permanent triangle set at an angle of twenty-three degrees. Fig. 156.

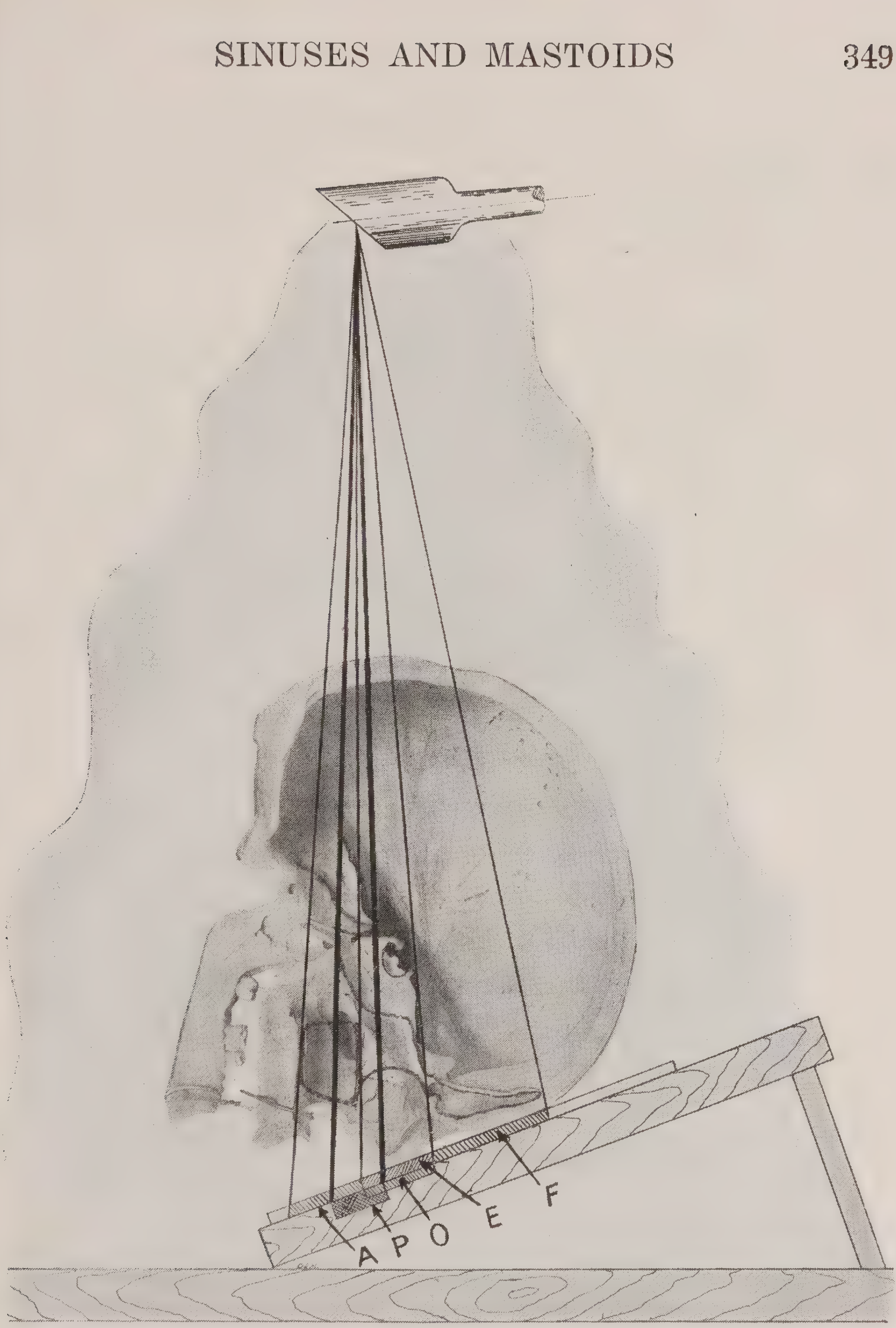


FIG. 155. Schematic drawing illustrating correct angle for posteroanterior accessory sinus examination. The heavy lines indicating projection of petrous portion of temporal bone on to the plate. A, antrum; E, ethmoids; F, frontal; P, petrous; O, orbit.

The patient is seated before an adjustable stand, or may lie prone on a table. The head rests face downward with the nose and forehead on an inclined plane. The inclination is such as to be comfortable to the patient. The head-

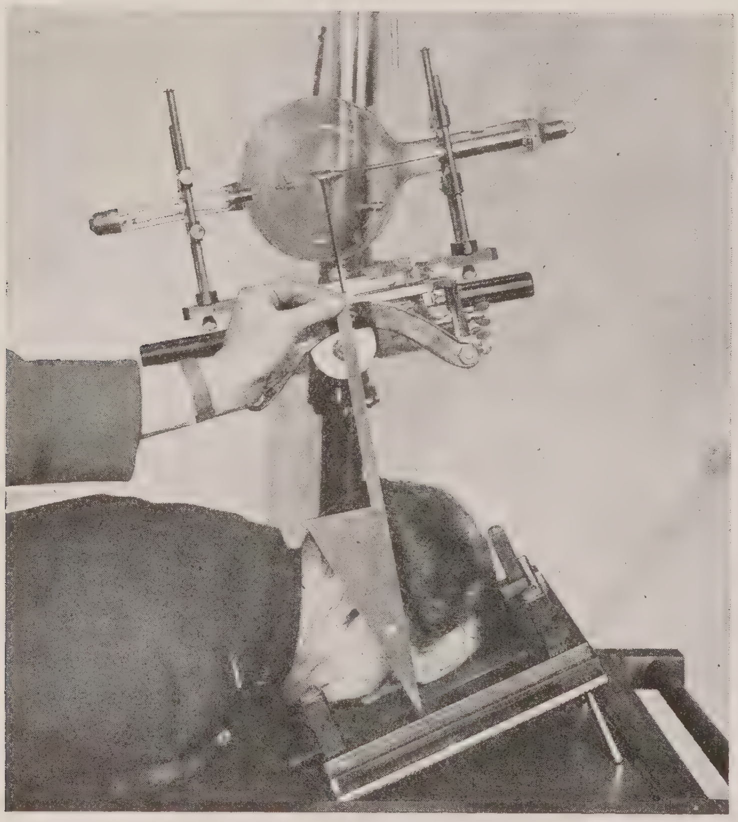
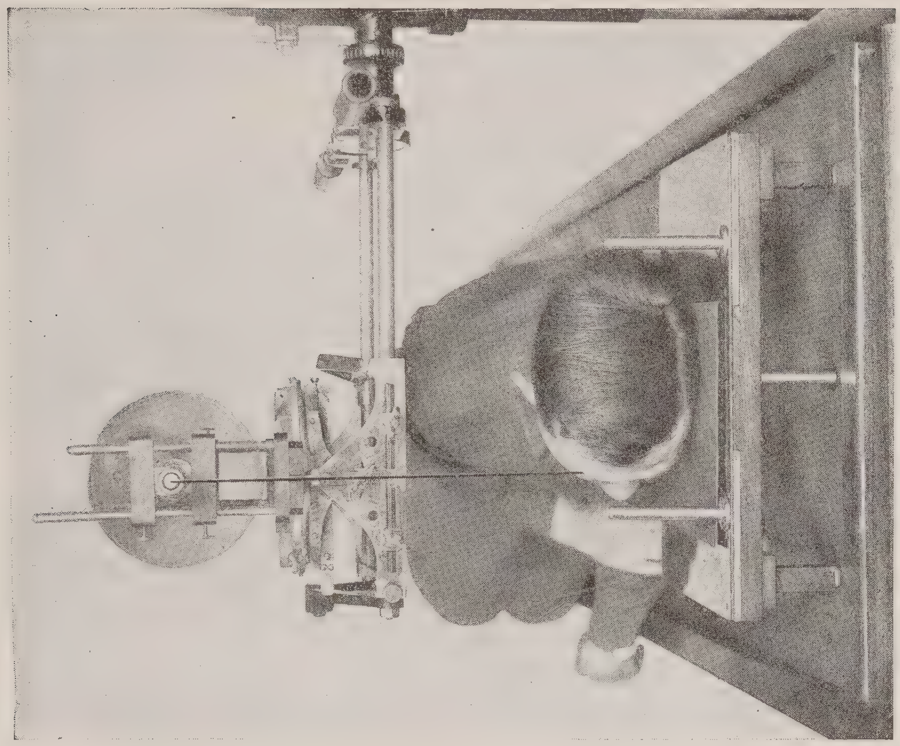


FIG. 156. Position for postero-anterior examination of accessory sinuses, head resting on nose and forehead, central ray entering head at angle of 23° from a line from external auditory meatus to glabella.

rest shown in the illustration has an angle of twenty degrees. If the patient is sitting, an adjustable rest is necessary to accommodate for the difference in the length of the neck and shape of the head.

The tip of the angle finder is placed opposite the glabella, the short arm passing across the external auditory meatus, the long arm extending upwards alongside the cone and



FIGS. 157 and 158. Position for lateral examination of accessory sinuses, head resting on side and central ray passing directly through floor of frontal sinus.

representing the direction of the principal ray. The cone is now brought into alignment with the arm of the finder and brought down on the head, making firm pressure.

For lateral plates the patient places the side of the head on the platform holder, the head is leveled so that the sagittal plane is parallel to the plate and the tube is centered so that the principal ray passes directly through the frontal sinus. This is to obtain a true representation of the depth of the sinus and the thickness of the anterior wall. The head is clamped firmly in place. Figs. 157 and 158.

For vertical examination there are two positions which will give satisfactory views of the sphenoid sinus and the adjoining structure. One, with the patient on his back and the head extended over the table, has been described in another chapter (page 310). The other is obtained by having the patient sit in front of an adjustable stand. The height and angle of the stand is adjusted to suit the height of the patient and to make him comfortable. The chin is extended as far as possible and placed on the plate which rests on the stand. The stand is also adjusted at such an angle that the plate rests against the clavicle. This places the entire neck on the plate, from the point of the chin to the clavicle.

The head is leveled and fastened securely in place with clamps. The tube is adjusted over the vertex and centered so that the principal ray passes downwards and backwards through the sphenoids. A straight edge placed alongside the head and passing through the sphenoid and center of the cone will show the point on the plate where the shadow of the sphenoid will be thrown. This must be at a point well posterior to the point of the jaw, but not so far back as to throw the sphenoid completely into the shadow of the larynx. If the sphenoid shadow is thrown at the level

of the angle of the jaw a good view of the ethmoid and sphenoid regions will be secured, Fig. 159.

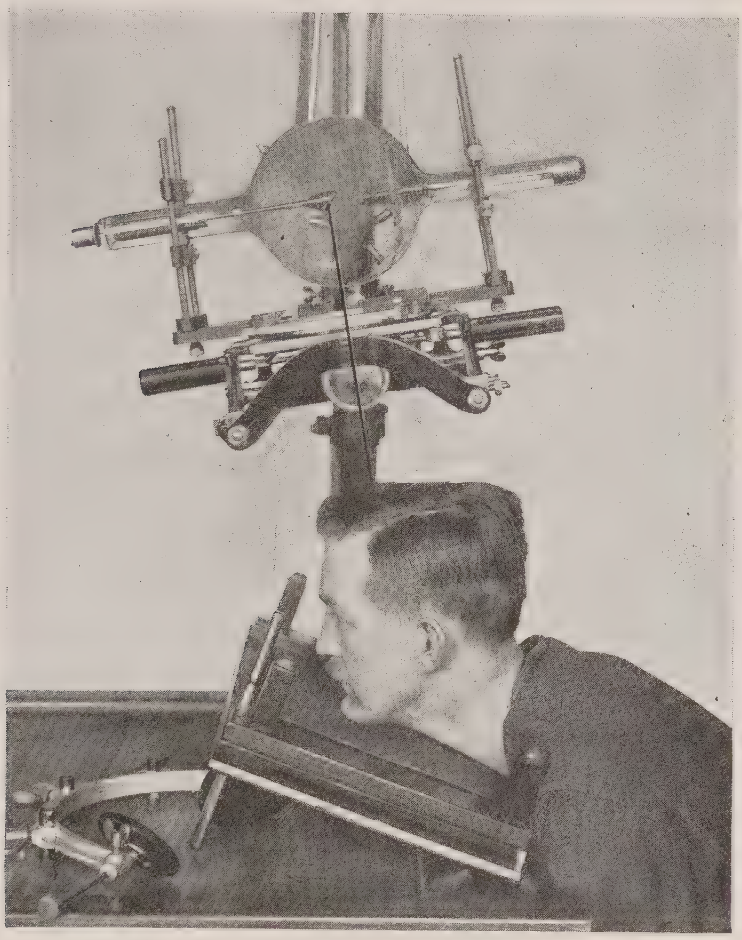


FIG. 159. Position for examination of sphenoid sinus. Chin resting on plate and extended well forward on plate. The height of table adjusted so that clavicle touches plate, thus bringing entire neck parallel with plate, tube centered over vertex so that central ray will project shadow of sphenoid on plate at about the angle of the jaw.

Interpretation of Mastoid Plates.—In case the pinna cannot be folded forward, due allowance must be made for the increased density over the mastoid cells caused by the shadow of the pinna. Postauricular edema will cause a haze over the cells, which must not be mistaken for in-

flammatory exudate. Inspection of the ear before radiographic examination will prevent this error, as allowance may be made for the increased density. Furunculosis in the canal is often accompanied by a slight cloudiness of the cells, which must not be mistaken for exudate.

The mastoid, being a pneumatic cavity, will show normally as a honeycombed structure with the cell partitions clearly outlined, so that the degree of the involvement will be determined by the sharpness of these partitions. A simple congestion or thin fluid will produce a general haze over the mastoid structure, but the cell walls will be clearly outlined. As the disease progresses and pus accumulates, the degree of obliteration of the cell walls will determine the extent of the disease or the amount of pus. If the condition has reached the point of bone destruction the necrotic area will show through the white blur of the cell involvement as a dark area. This usually occurs over the line of the tegmen tympani, representing an epidural abscess, or over and below the knee of the lateral sinus as a perisinus abscess.

This dark area must be distinguished from a large cell in the midst of a group of small cells. This can usually be done by comparison with the opposite mastoid. As a rule the two mastoids are similar in structure. When there is a large or small cell on one side there is usually a corresponding cell on the opposite side. Then, too, a necrotic area will have hazy edges while a clear cell will be sharply outlined.

Complete obliteration of the cell area must be differentiated from sclerosis. This is a condition caused by replacement of the cell structure by dense bone, and the shadow on the plate will therefore be structureless. The area resembles the bone in the rest of the skull, with a clear-cut outline of the sinus showing through. This proc-

ess can be so extensive as to involve the entire area including the region of the antrum, thus showing no detail at any point.

A condition may arise in which necrosis has occurred in the sclerotic area, a cholesteotoma. This will show as a dark spot within the sclerotic area. Usually there is a lighter area in the dark portion which represents a mass of débris in the necrotic cavity.

In the event of a fracture or injury extending through the mastoid structure stereoplates are necessary. These cases nearly always show mastoid change due to the presence of blood or infected material.

In the event of the involvement of both mastoids dependence must be placed on the history and clinical evidence.

The size of the cells plays an important part in the prognosis. A large pneumatic mastoid with large antrum cells is more likely to clear up without operation than one with small cells, as the smaller cells are more apt to clog and stop drainage.

Many cases which have been operated and have not properly cleared up will reveal cells remaining in the mastoid process. These contain granulations which keep up the discharge and prevent healing.

In the case of children, it must be remembered that the mastoid cells do not develop until about the age of five years, so that an examination of a child under this age will give no useful information.

Interpretation of Accessory Sinuses.—Here, as in mastoids, there are pneumatic cavities which in a normal condition allow the rays to penetrate readily and produce dark areas on the plate. When pathological material is present the transparency is reduced, depending on the extent of the involvement.

In the examination of the frontal sinuses a very important factor to be considered is the depth of the sinus and the thickness of the anterior wall, as viewed on the lateral plate. A sinus with a thick wall will naturally show less transparency than the same sinus with a thin wall. Hence a sinus with a thin wall and containing granulations or thin pus will cast the same transparency as the same sized sinus with a thick wall but clear of pathological material. A deep sinus will normally be more transparent than a shallow sinus. One must remember that one or both frontal sinuses may be absent.

In the case of absence of frontal sinuses, the lateral plate will reveal solid bony detail in the frontal region, while a single frontal will reveal bony detail through the transparent area of the sinus which is present. If both are present a clear area will show on the lateral plate.

It is impossible to distinguish between the shadow cast by pus or by dense granulations in the sinuses. The diagnosis must be made of occlusion of the sinuses by some dense material. The case history will help to a great extent.

The ethmoid region must be studied in both the anteroposterior and lateral positions,—the diagnosis resting on the density of the region and the degree of obliteration of the septa. Plates made in the vertical position will indicate the affected side and show whether the anterior or posterior cells are involved.

The ethmoid cells are sometimes very extensive and show above, behind and below the orbit. In the examination of the maxillary antrum the degree of obliteration of the fine lines of the walls determines the amount of involvement, although mucoid material will cause practically no change in the shadow. It may be necessary to puncture the antrum through the nose to clear up the diagnosis between granulations and pus.

TEETH AND MAXILLAE

In the study of the teeth dental films are more satisfactory than plates. Accompanying illustrations will describe the proper adjustments of tube and films or plates. Plates are used when the films cannot be put into the mouth, or when a large area is required to be shown.

Placing the Film.—Observe the following hints in placing the films in the mouth. All sharp corners of the wax paper covering must be folded over and softened, and the films themselves will become more soft and pliable by bending (not breaking) them over the end of the finger and thumb so that they will take the curve of the palate or inner surface of the mandible more readily. To prevent gagging, the patient is told to breathe deeply through the mouth while the film is being placed in position. This causes the tongue to be carried far back into the pharynx where it need not be pressed upon. In very troublesome cases spraying the palate and pharynx with camphor water, in addition to the above precaution, adds greatly to the chance of success. Be sure that the film is far enough into the mouth to include all of the root structure. The position of the film should be carefully noted after the patient's thumb or forefinger is in place to hold the film, since the wax paper moves easily on a surface wet with mucus, and the patient's hold may relax as the operator removes his hand. For the upper teeth no additional covering over the wax paper is necessary or even desirable, and there is no better film holder than the patient's left thumb for the upper teeth on the right side, and the right

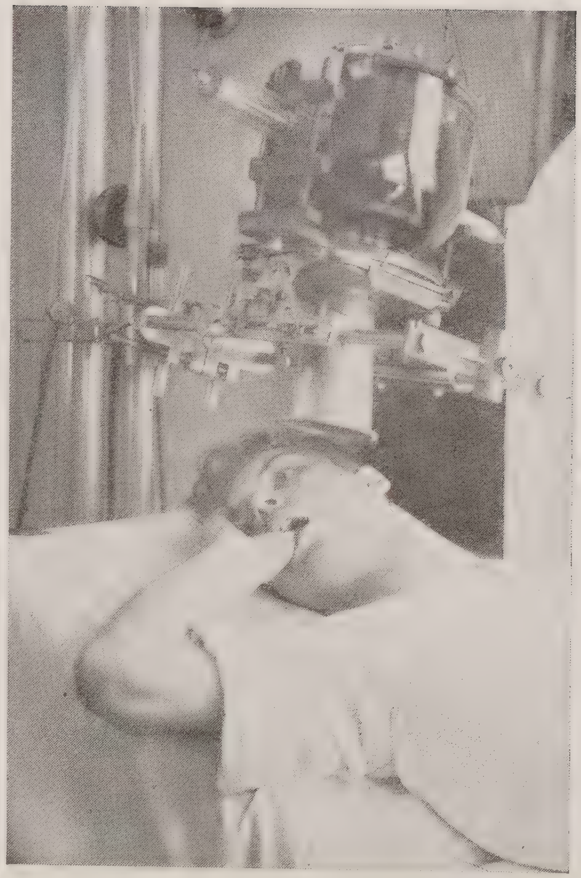


FIG. 160. Position of patient, film and tube for exposure of upper molar region. Note elevation of head and slight downward tilt of cone.

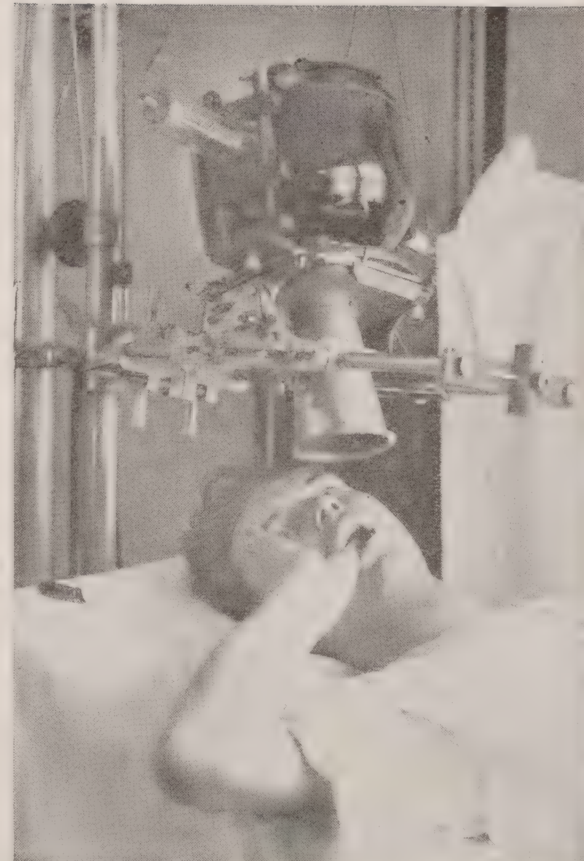


FIG. 161. Adjustment for exposure of upper bicuspids, canine, and lateral incisor. Note that cone tilts more than in Fig. 160. This same tilt of cone is used for exposing the central incisors.

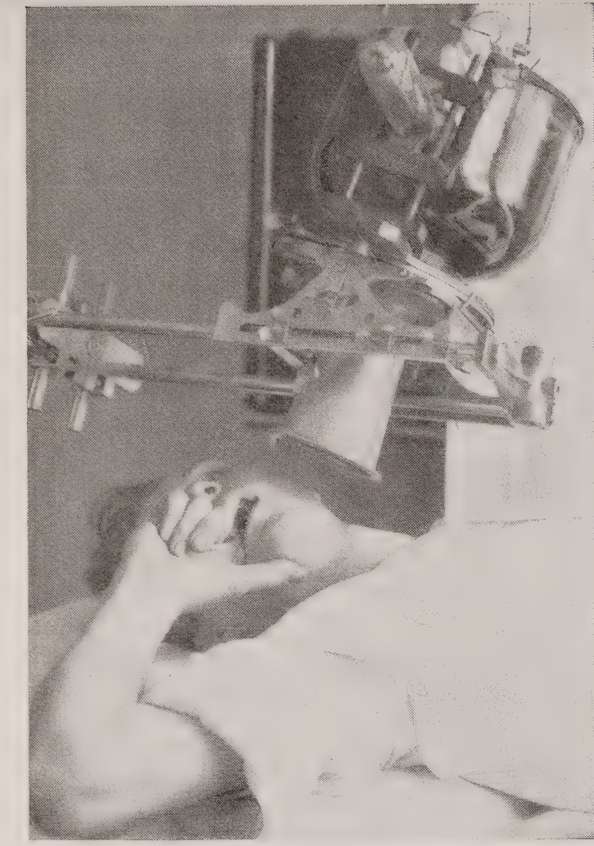


FIG. 162. Adjustment for exposure of lower molars. Head is lowered to level of body. Note position of fingers and thumb, also that cone is tilted slightly upward.

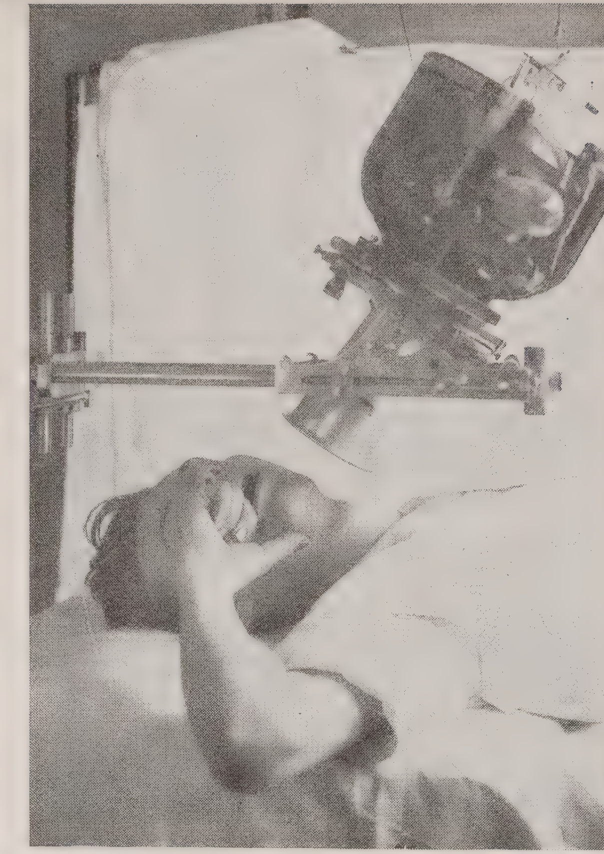


FIG. 163. Adjustment for exposing lower bicuspids, canine, and lateral incisor. Note extension of chin, also marked upward tilt of cone. This same upward tilt of cone and extension of chin apply to the lower central incisors.

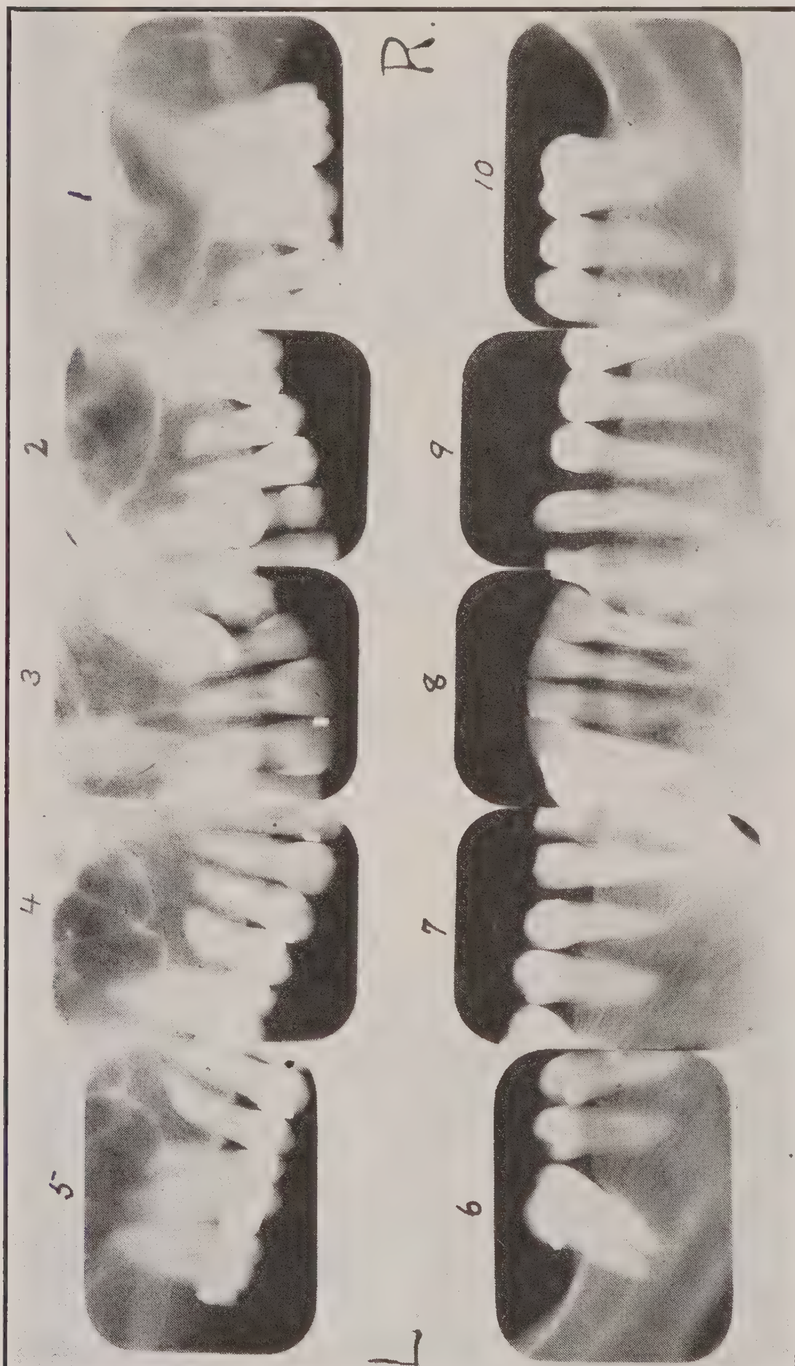


FIG. 164. Normal teeth except for unerupted canine upper right. Note the firm attachment of the teeth to the alveolar process, and also the cancellous structure of the alveolus. The numbers from 1 to 10 show the order in which the films have been exposed. There is slight absorption of the alveolar margin in the lower incisor region.

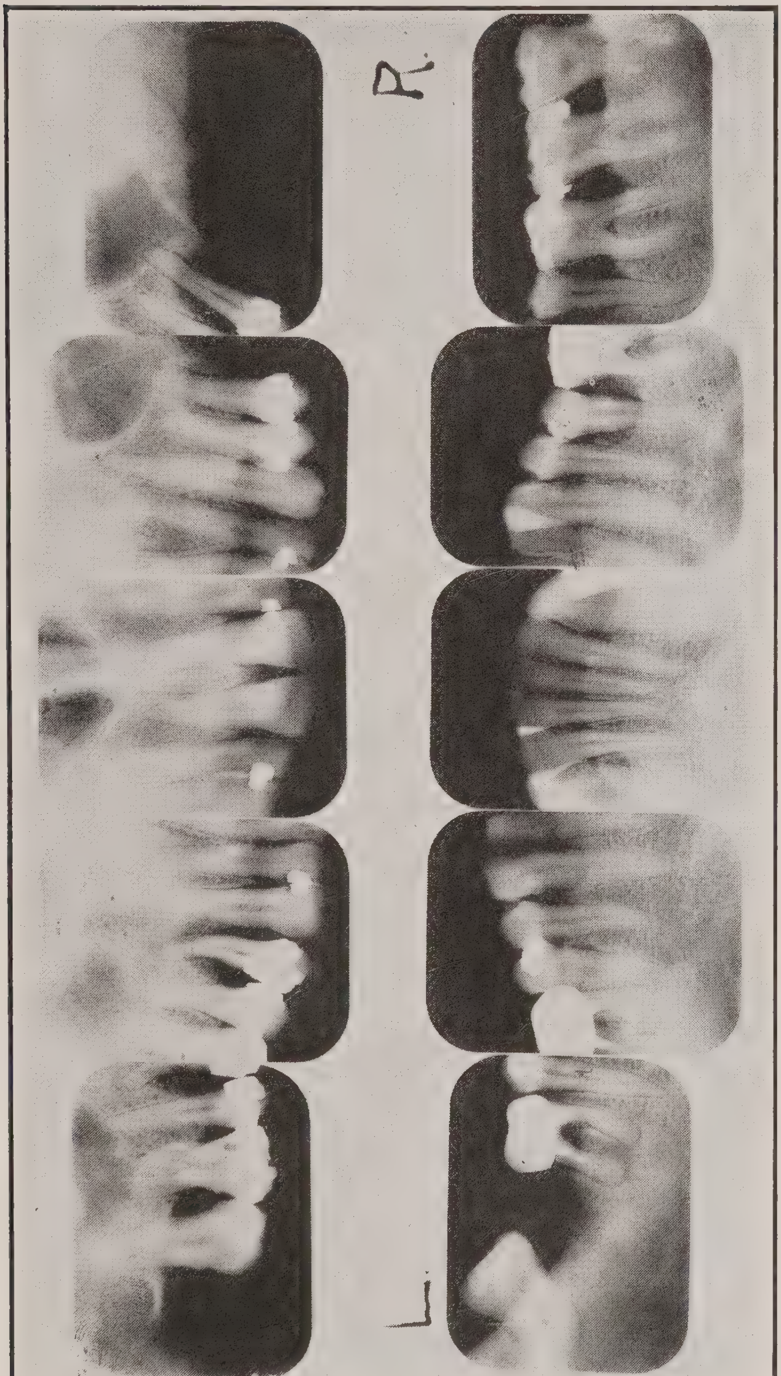


FIG. 165. Localized areas of destruction of the alveolar margin, or subgingival abscess, second bicuspid upper right, first bicuspid upper left, first molar lower left, canine lower left, second bicuspid and first molar lower right. Hypercementosis of roots of first molar lower left.

FIG. 166. Sarcoma of mandible involving median incisors and left lateral incisor, probably also beginning involvement of the other teeth shown.

FIG. 167. Acute abscess right upper central and lateral incisors. Note that abscess is not sharply defined. Acute abscesses sometimes do not cast definite shadows.

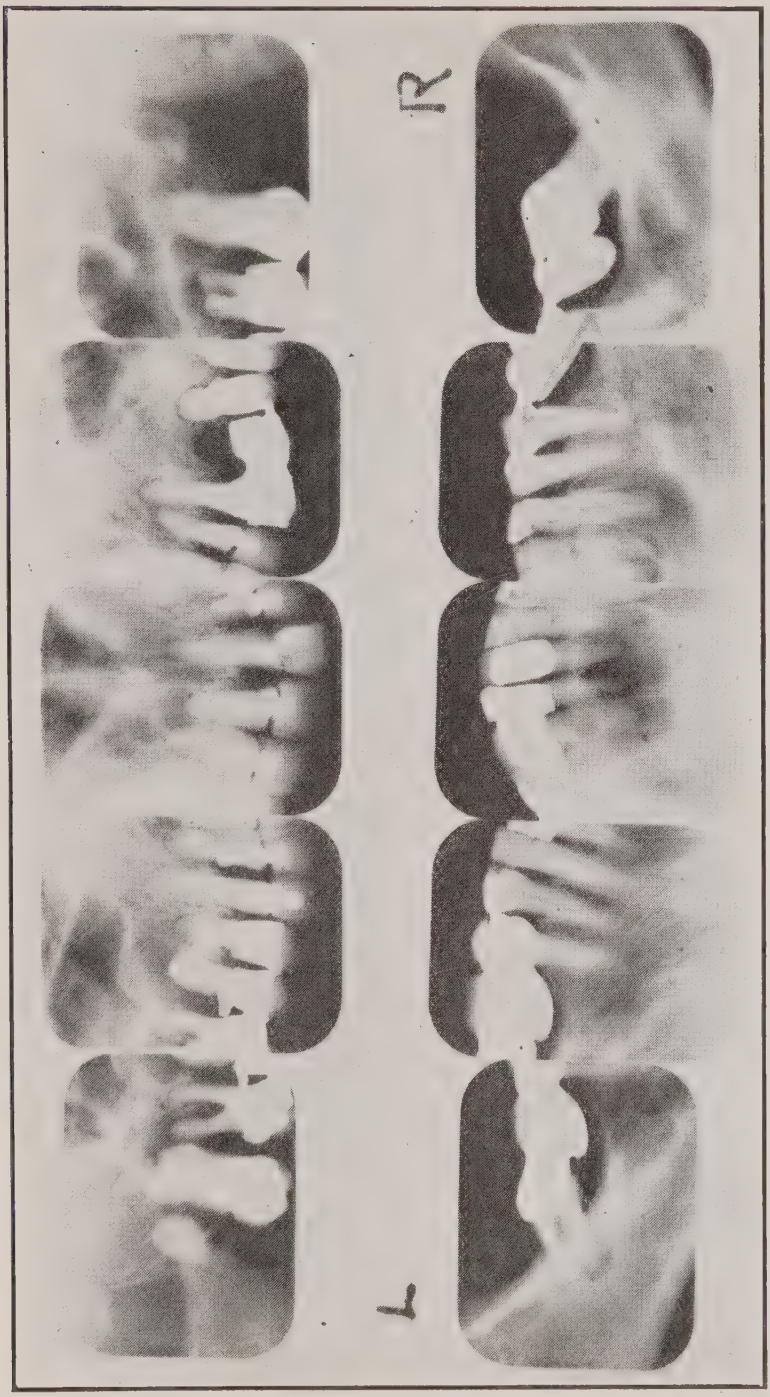


FIG. 168. Multiple chronic apical abscesses, with areas of extensive destruction of the alveolar margin. Unextracted root third molar upper left.

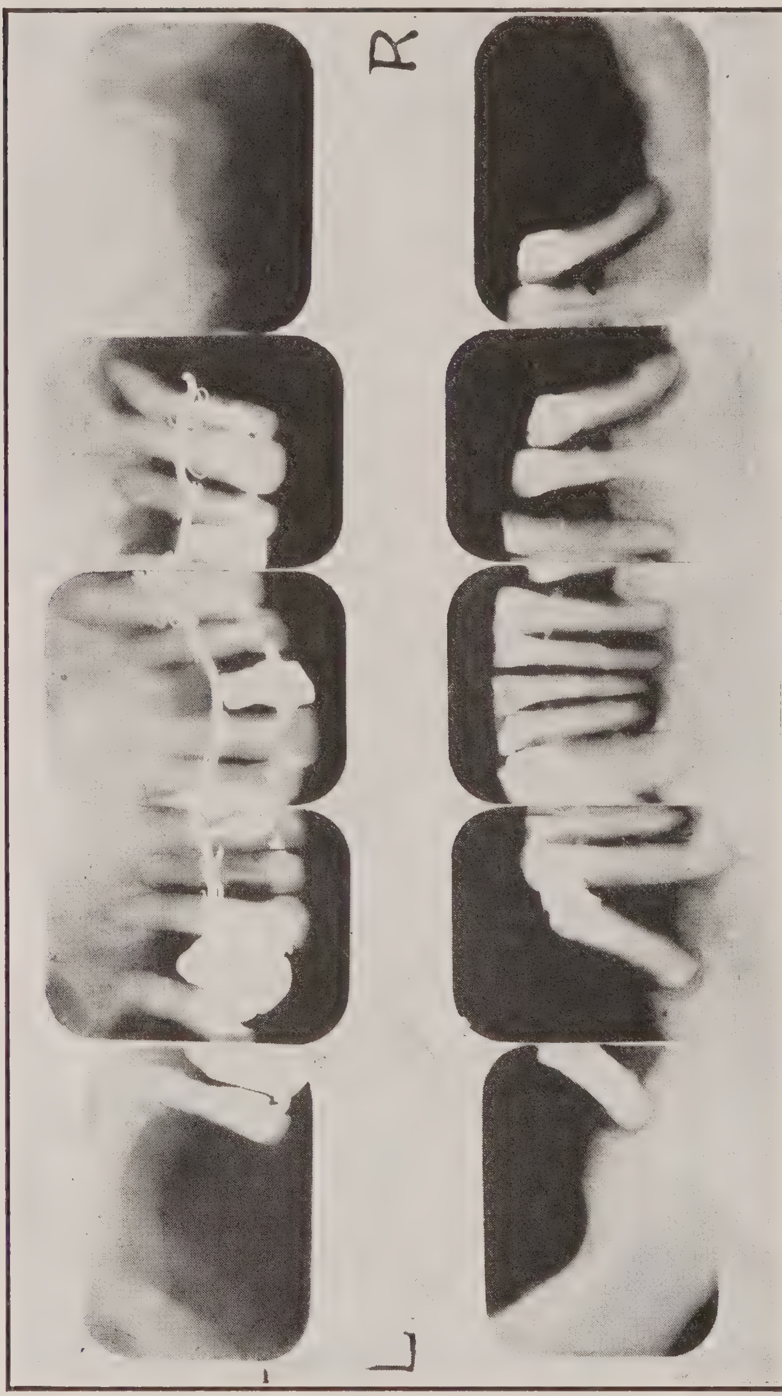


FIG. 169. Advanced pyorrhœa.

thumb for those on the left side. The pressure of the thumb must be firm, and the fingers should rest on the opposite side of the face to prevent unintentional motion of the hand. In all instances the operator must mold the film to the contour of the maxillæ and denote by the firmness of his own pressure how the patient shall hold it.

For the lower jaw the films should be wrapped in soft tissue paper, such as a paper napkin. This prevents slipping and is also more comfortable to the patient. It is absolutely essential that the patient's tongue be completely relaxed in order that the film may be carried back far enough to reach well beyond the third molar, and deep enough to reach well below the apices of the roots. The palmar surface of the index finger of the opposite hand is preferred for holding the films against the lower teeth.

Exposure.—The patient should hold his breath during the actual exposure whether it is for one second or twenty seconds.

The proper angle of exposure must be determined by the contour of the patient's maxillæ, and the tooth shadow should be approximately the same length as the tooth.

For angle of exposure see Figs. 160-163.

Interpretation.—The x-ray study of the teeth and maxillæ is to be considered from the viewpoint of dentistry without injury, and as well from the viewpoint of wounds incident to war and, therefore, of surgery. The former has more to do with the general health and efficiency of the soldier, while the latter involves the repair and restoration of these very important parts after injury.

The reader is advised to acquaint himself with the structural and regional anatomy of the teeth and maxillæ, and also to study some recognized authority on the pathology of these structures. The accompanying illustrations show practically all of the types of pathological

FIG. 170. Abscesses involving unerupted teeth.

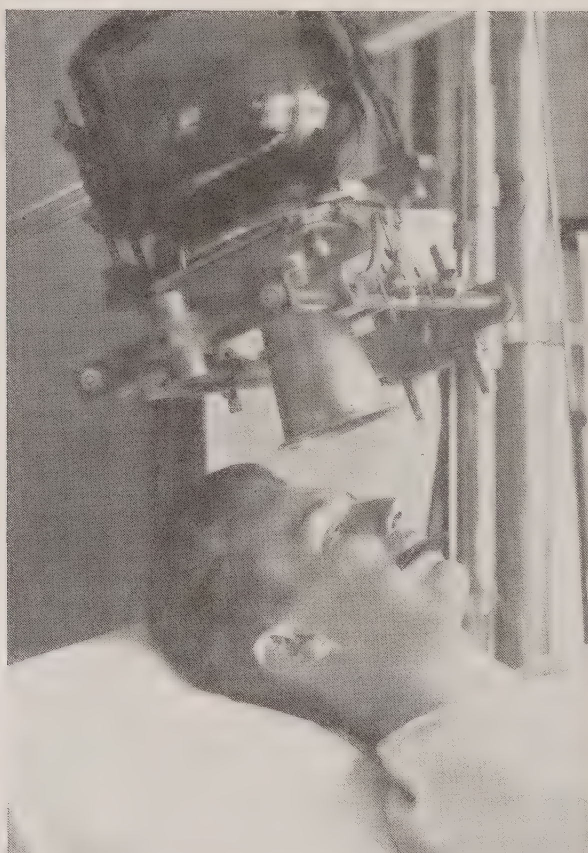


FIG. 171. Adjustment for exposure of anterior portion of upper jaw. Note large film held between the teeth. The teeth shadows will be very much foreshortened.

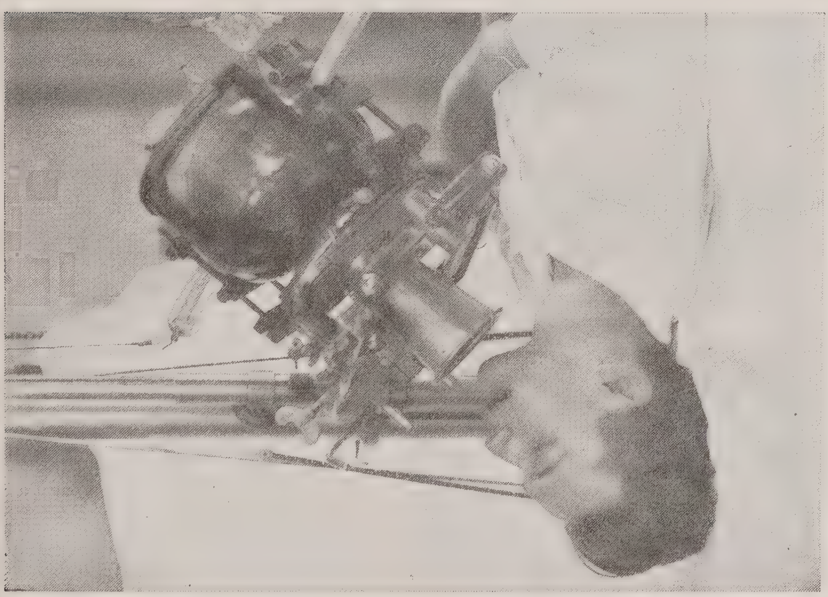


FIG. 172. Adjustment for exposure of anterior portion of mandible with large film in mouth.

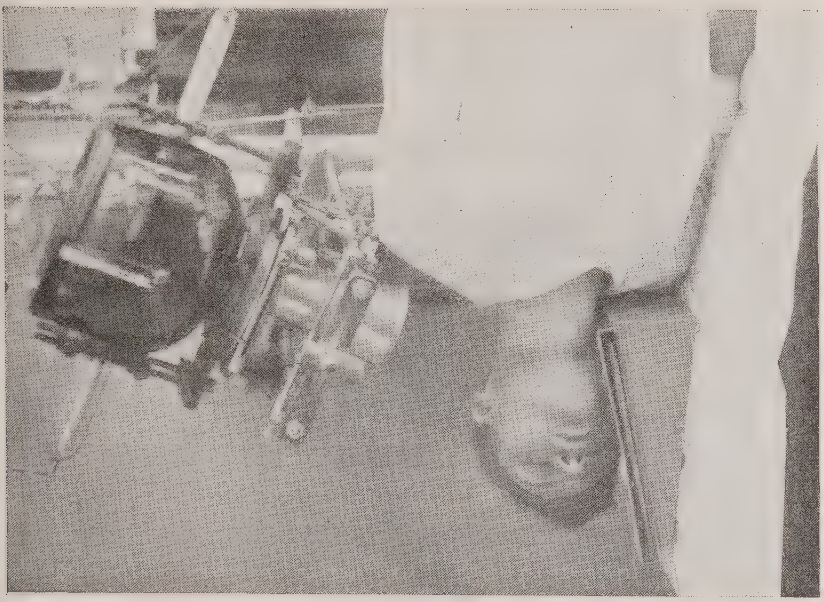


FIG. 173. Adjustment for exposure of posterior two-thirds of mandible, the articulation of the jaw, and the zygoma. Note plate-holder by means of which plates may be handled for stereoscopic exposures. The tube should be shifted laterally. Chin is in extreme extension.

lesions about which we are herein concerned, except injuries. Figs. 164 to 170.

It is difficult to anticipate the sort of injuries one has to deal with in military surgery, and therefore difficult to give definite instruction in the part taken by the roentgenologist. The following illustrations serve to show the proper adjustments for the different parts of the jaw bones, and may be taken as guides in most instances. The object is to have the central rays pass in such a direction that the shadows of the teeth on the near side of the face will not fall in the area that is to be examined. Figs. 171 to 174.

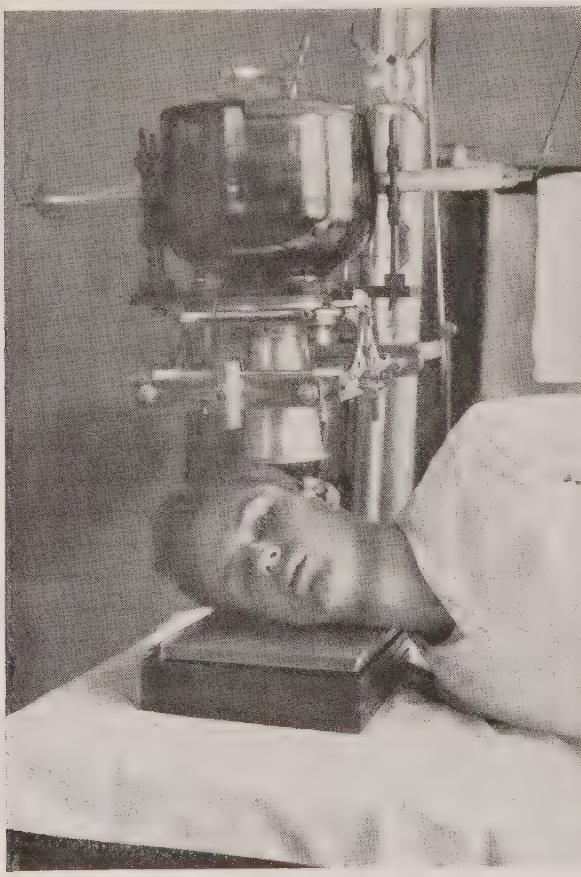


FIG. 174. Adjustment for exposure of upper jaw.

THORACIC VISCERA

Methods of Examination.—The thoracic viscera may be studied either by fluoroscopy or by radiography. Fluoroscopy is useful for a preliminary orientation, to view the movement of the diaphragm, to study the movement of fluid levels in the pleura and in the lung and to observe the mediastinum in the various oblique positions. It is indispensable in the x-ray study of heart and aortic conditions. It is of uncertain value in the recognition of infiltration in the lung as in tuberculosis. For this purpose a plate examination is indispensable.

Stereoscopic plates are of value to indicate the depth of a pulmonary lesion; they will differentiate between pulmonary and pleural or extrapulmonary conditions. In tuberculosis, especially, they resolve the shadows into their components and, thus, give a truer idea of the density of the infiltration. Stereoscopy can, however, usually be dispensed with, as the data it furnishes does not materially differ in character from that found in a good single plate. A more potent reason for dispensing with it in army work is the additional time and trouble involved and the difficulty of obtaining large plates in sufficient number.

Time.—The time of a single exposure should not exceed two seconds. If the current is not sufficient to obtain a proper exposure in that time, the use of an intensifying screen, which must be as nearly perfect and free from grain as possible, is advised. Exposures of less than a second are desirable, but at the present time they are not easily accomplished in the routine work of large hospital

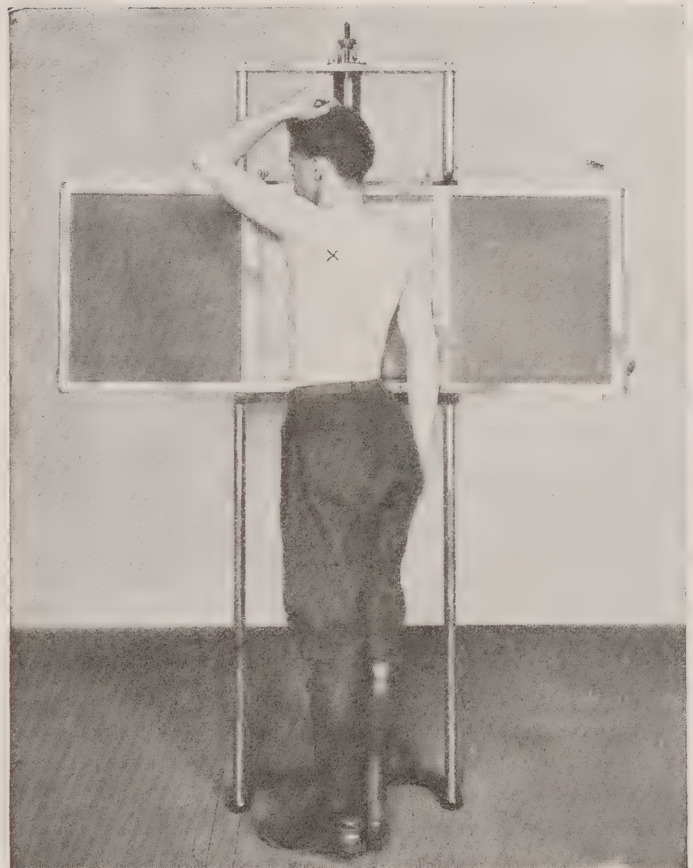


Fig. 175. First oblique position. Right anterior side of patient against the plate or screen; left posterior side toward tube. Tube focussed opposite X.

Fig. 176. Second oblique position. Left anterior side of patient against plate; right posterior side toward tube. Tube focussed opposite X.

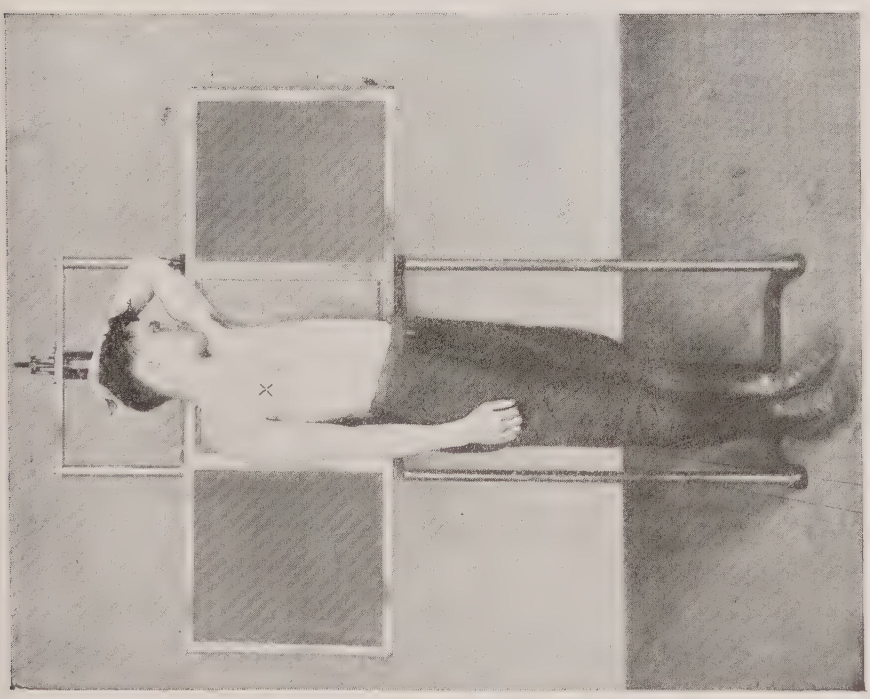


FIG. 177. Third oblique position. Left posterior side of patient against plate or screen; right anterior side toward tube. Tube focussed opposite X.

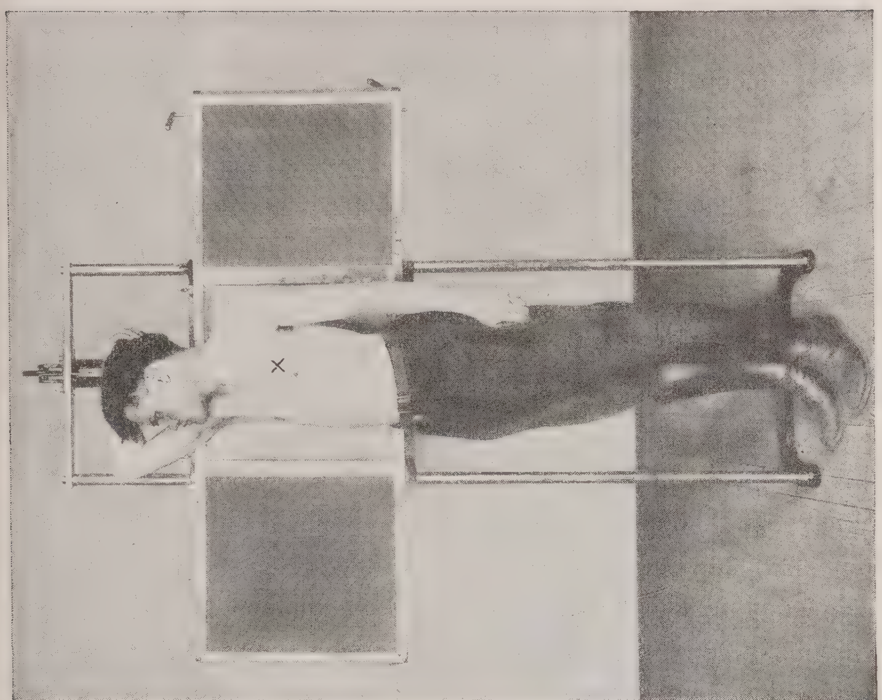


FIG. 178. Fourth oblique position. Right posterior side of patient against plate or screen; left anterior side toward tube. Tube focussed opposite X.

laboratories, where they consequently increase the number of unsuccessful plates.

Position.—The position of the patient should always be upright, standing or sitting, and only when there are indications to the contrary should the position be prone or

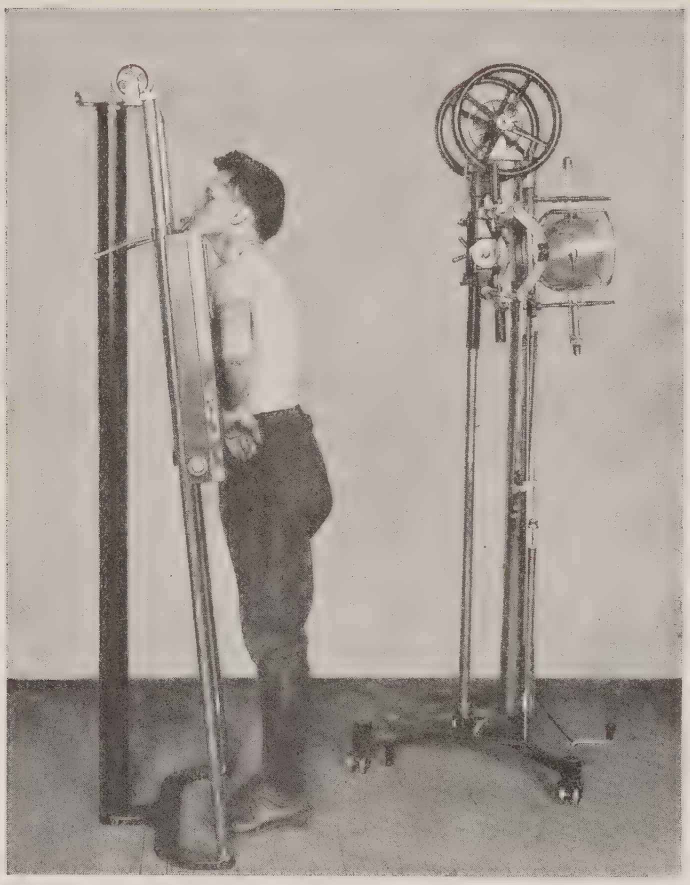


Fig. 179. Dorsoventral (postero-anterior) position; chin raised and neck extended so as to avoid turning of head to one side or the other; focus of tube approximately at level of the 4th thoracic vertebra; distance 26 inches.

recumbent. In the upright position it is best to so adjust the plate that its upper margin will touch the under surface of the chin, and the upper part of the chest should be brought as near to the plate as possible. The arms should be slightly raised and rotated inward, so as to remove the shadows of the scapulæ from the lung field. Raising

the arms too high obliterates the apices. If the plate cannot be placed as stated, it is advisable to extend the neck and thus raise the chin, but it is not desirable to turn the head to one side or the other, because it causes distortion of the trachea. This position, which will be called the dorsoventral because the tube is at the back of the patient and the plate in front, is the one most commonly employed (Fig. 179). Other positions which are necessary to bring out certain structures in the chest are the various oblique positions. These are the following: first oblique—the tube behind at the left, the plate or screen in front at the right of the patient (Fig. 175); second oblique—the tube behind at the right, the plate in front at the left of the patient (Fig. 176); third oblique, a dorsal reversal of the first (Fig. 177); fourth oblique, a dorsal reversal of the second (Fig. 178). The first and third oblique bring out most clearly the structures in the posterior mediastinum and are most commonly used to demonstrate the esophagus. The second and fourth oblique are best used to bring out the right side of the heart and particularly the ascending aorta.

The focus of the tube should be at the level of the fourth thoracic vertebra when using the dorsoventral position. This shows the apices clearly and projects the diaphragm downwards so that more lung tissue at the bases can be seen.

The exposure should be made at *nearly* full inspiration. Absolutely full inspiration is not advisable because most patients strain in doing so, making it more difficult for them to hold their breath and causing frequent irregularities in the appearance of the diaphragm, especially the right, due to a spasm of the diaphragmatic muscle.

Types of X-Ray Chest Plates.—No two chest plates, even of normal individuals, are alike. Many different physical conditions are imposed by the conformation of

the chest and all may be within normal limits. Variations in the technique of the examination may give unusual appearances that must not be mistaken for abnormalities. It is therefore necessary, in deciding whether the shadows on the plate are due to pathological lung conditions, to take into account these normal variations. Failure to do this accounts for most of the disagreement among roentgenologists in the interpretation of plates. It is not possible to describe adequately the characteristics of normal plates. They must be seen and studied. The following suggestions however are made.

The Normal Lung.—There is, strictly speaking, no such thing as a normal or typical lung plate. The size, shape and graphic appearance of the lung fields vary with the age of the individual, the shape of the thorax and with previous pulmonary disease. As far as the x-ray is concerned the lungs consist, on the one hand, of the great mass of air-containing vesicles and, on the other, of a network of bronchi, blood vessels and lymphatics. The former do not cast any shadows on the plate and are responsible for the aerated lung fields. The latter intercept the ray and produce a shadowy network throughout the lung radiating from the root, decreasing in distinctness and width toward the periphery where they are barely visible. It is the difference in the prominence of these markings in different individuals, or even in the same individual when the technique is varied, which gives rise to diverse types of normal chest plates.

All the structures above enumerated contribute to the production of these markings, although to different extents; the blood vessels, especially toward the periphery of the lung, are responsible for most of them. The bronchi do not cast distinct shadows except at the root where they are merged with the hilum shadows and are sometimes seen

in cross section or in double contour. It is, therefore, not possible to identify the bronchial tree as such on the plate or to bring any abnormal infiltrations into relation with it.

Much of the difference of opinion in regard to plates, especially in tuberculosis, has arisen from a wrong interpretation of these markings. Their unusual prominence has no significance in itself and is not necessarily an evidence of disease of the lung. Thus, if the contrast between the aerated lung fields and the airless branchings is enhanced, the latter will seem more prominent. This may be seen in emphysema, in older people with induration of all the tissues, especially the blood vessels, and in the case of deposits of dust and other foreign particles in the lymphatics. It will also occur whenever the blood vessels are engorged, as in circulatory disease, and when the examination is made in the prone position. The markings in the lower lobes are usually wider, especially along the borders of the heart where an appearance of fairly broad, branching shadows is not to be considered abnormal.

Certain shadows are frequently encountered in plates which have no relation to disease processes. It should be understood that if any small area of the plate is scrutinized by itself it may appear to contain shadows. These are usually points of bifurcation or crossing of blood vessels or bronchi. Other larger and denser shadows, varying in size from two to five millimeters or more, are probably calcareous lesions which are found in a large percentage of otherwise normal lungs. They have no clinical significance. The shadows cast by female breasts and pectoral muscles should be noted, and inferences as to the aeration of the lungs must not be drawn from a wrong interpretation of them. The same is true of the scapula, the shadow of which overlaps the axillary portion of the

chest if the arms are not brought forward or rotated inward during the examination. The upper limit of the apex is usually at the level of the lower border of the second rib posteriorly. If for any reason the apex is depressed, as in cases of chronic tuberculosis, a shadow may be seen just below and parallel to this rib.

The *hilum or root* of the lung shows as an ill-defined mass of shadows which are produced by the blood vessels, large bronchi and lymph nodes near the mediastinum. It is irregular in shape and varies considerably in size and density, depending upon the age of the individual and previous respiratory infections. Here again there is no normal type. Usually the shadow does not extend laterally more than an inch beyond the spine and is of moderate density. However, in estimating the significance of the hilum shadows it should be remembered that in nearly all adults pathological changes have occurred. Thus the bronchial nodes, as a result of infection, tuberculous or otherwise, are usually enlarged, indurated and calcareous, and the tissues about them may be thickened.

They are only an evidence of the usual adenopathy found in adults, and should be disregarded unless they are very marked. The hilum shadows are more prominent in the aged and in cases of emphysema. If the heart is median in position or hypoplastic, more of the hilum will be exposed and will, therefore, appear larger.

The *trachea* takes an almost median course through the upper mediastinum and bifurcates at the level of the fourth dorsal vertebra. It is usually well seen on the plate and a deviation in its course or a constriction are readily noted. The bifurcation and the outlines of the larger branches of the bronchi are often visible in a well-exposed plate through the denser structures of the mediastinum. The rest of the bronchial tree is invisible and indistinguishable in the

lung fields. For this reason a localization of the bronchi is not generally possible and such a localization is probably of little importance.

Localization of the lobes of the lungs has a greater value and is to a certain extent feasible. A knowledge of the topographical anatomy of the fissures is essential. On the left side the fissure between the upper and the lower lobes begins behind at the level of the third dorsal vertebra, extends obliquely down to the axilla and then almost transversely across the chest to the sternal end of the sixth costal cartilage. On the right side the upper interlobar fissure runs across the chest to the sternal end of the fourth cartilage. By means of these landmarks it is to a certain extent possible to refer shadows to individual lobes. This must, however, be done with caution because, in the middle area of the lung, the lobes overlap. To localize shadows in this region, stereoscopic examination and the oblique positions are of value. In a fair proportion of cases the right interlobar fissure is sharply outlined on the plate due to pleural thickening, thus serving as a guide in this region.

Pulmonary Tuberculosis—

Relation of the X-Ray to the Clinical Examination.—There are definite limitations to the x-ray diagnosis of tuberculosis, and it is no reflection on its value to emphasize them. In order to cast a shadow of sufficient size and distinctness to be recognized on the plate, a mass of tuberculous tissue in the lung must be some millimeters in diameter. It therefore follows that a plate may give no evidence of an early tuberculous process. On the other hand, it is only fair to state that at this stage there are in most cases no physical signs or only equivocal ones. In the vast majority of cases in which the physical signs of so-called incipient tuberculosis are found, a careful plate

examination will reveal the shadows of infiltrations. Moreover, in a fair percentage of cases the extent of these infiltrations is such as to indicate that the process is no longer incipient. In the more advanced forms of tuberculosis the plate almost invariably shows more extensive involvement than is indicated by the physical examination.

The earliest infiltrations of tuberculosis are but rarely visible on the fluoroscopic screen, even at a time when the plate will definitely show them. In the absence of such infiltrations, a fluoroscopic diagnosis of early apical tuberculosis is often made because of deficient aeration in one or the other apex. Such a change in aeration may depend on several causes other than tuberculosis and, therefore, is not of great diagnostic value. The expedient of having the patient cough and noting whether the apex clears up is an uncertain one and will not definitely distinguish an atelectasis from an infiltration. The fluoroscope should therefore be used in the diagnosis of early tuberculosis only through necessity, not by choice. Even in the advanced forms of tuberculosis this method will not reveal the extent of the process as faithfully as the plate, but is of great value in the study of the movement of the diaphragm, since in a considerable percentage of the cases of early tuberculosis the diaphragm is partly or completely immobile on the affected side. This appears to occur irrespective of the presence of diaphragmatic adhesions.

X-Ray Evidence of Early Tuberculosis.—The early lesions of tuberculosis generally appear in the upper lobes, and are usually found just below the clavicle and not necessarily above it. Frequently they occur near the apex of the axilla, and appear usually as a group of faint homogeneous shadows, indistinct in outline, varying in diameter from several millimeters to a centimeter. The pathological basis of these shadows is probably an agglomeration of tu-

bercles surrounded by a pneumonic exudate. As these lesions progress the shadows increase in number so that they coalesce, producing a larger homogeneous shadow. A caseation of the lesions, which usually supervenes, is represented on the plate by an increase in the density of the shadows which become more distinct and irregular in outline. In most cases, sooner or later, there is noted a development of fibrous tissue which shows as fine strands in the infiltrated area.

While the radiographic image varies according to the state and duration of the lesion, yet the foregoing description represents a fairly frequent form of early tuberculosis.

In order to diagnose incipient tuberculosis there must exist one or a group of infiltrations as above described; to base it on the presence of strands radiating from the root of the lungs will lead to frequent error. The importance of observing a careful technique is nowhere so great as in the diagnosis of an early lesion, because here it is vital to eliminate the errors and confusion resulting from an undue prominence of the lung markings.

Advanced Tuberculosis.—In the progress of the disease, as shown by the plate, a great diversity of appearances is produced, in the first place, by the slow or rapid extension of the process and, in the second place, by a change in the appearance of the shadows due to the chronicity of the lesions. In general, the density of the infiltration diminishes from above downward, and in even the most advanced cases the bases show considerable aeration. Although the nodular character of the tuberculous process may be obscured by an exudate or by fibrosis, evidences of it can usually be found in the peripheral or more recent lesions. The shadows vary from numerous discrete nodular deposits, submiliary in size, characteristic of tuberculous broncho-

pneumonia, to complete consolidation. On the other hand, the appearance of consolidation may be simulated by the confluence of shadows in cases of tuberculous bronchopneumonia.

In all but the most rapidly developing forms of tuberculosis, there will be found somewhere in the lung evidence of fibrosis. This is most marked in the oldest lesions in the upper lobes. It consists of coarse linear or broader shadows which commonly extend from the upper mediastinum into the affected lung. The effects of these strands of connective tissue are seen frequently in a displacement of the thoracic viscera and a deformity of the thorax. The trachea is commonly pulled over toward the side of the oldest lesion and may take a tortuous course through the upper chest. The displacement of the trachea to either side may thus occasionally give rise to the physical signs of a cavity near the border of the sternum. The heart may also be displaced and there may be a scoliosis of the spine and retraction of the ribs and of the chest wall. The diaphragm may be drawn up and deformed by adhesions. The chronic forms of tuberculosis are definitely shown in cases where emphysema and asthma are also present. Emphysema, in these cases, usually masks the physical signs but reveals the infiltration on the plate more clearly by contrast.

Progress of the Lesion.—The appearance of the lesion in a nonprogressive case may be unchanged over a long period of time. On the other hand, a rapid extension of the process may sometimes be noted. For example, after a hemorrhage or the overflow of secretions from a cavity in an upper lobe, a dense shadow due to a caseous lobar or bronchopneumonia in the lower lobe may be seen to develop in a short time. Tuberculous infiltrations once noted in the plate are usually permanent. Even with an improvement in the symptoms the shadows persist, though

they may be changed somewhat in appearance by fibrosis or calcification. The only exception to this statement appears to be in the case of the pneumonic process which surrounds the early lesions. For example, in the acute stage of incipient tuberculosis there is occasionally seen a rather extensive shadow in an upper lobe, much of which disappears after the period of acute illness is gone. A small permanent remnant of the infiltration will indicate its tuberculous nature.

In cases of suspected tuberculosis we may find an infiltration of a lower lobe. In deciding the nature of such a shadow the coincidence of a process at an apex is of the greatest importance. It may be taken as a working rule which applies to the vast majority of cases, that in adults an isolated infiltration in a lower lobe is probably not tuberculous. It should provisionally be attributed to some other condition, such as lung abscess or bronchiectasis or an indurative pneumonia.

Tuberculous Cavities.—Cavities are not necessarily an evidence of far-advanced tuberculosis, as they may occur in cases with only a small involvement of an upper lobe. Occasionally they may be found well encapsulated, with no evidence of infiltration elsewhere in the lung. They are usually easy of recognition on the plate or fluoroscope, and are often discovered when physical signs are lacking. They appear as well-defined, ringlike structures, which are imbedded within the infiltrated lung with a connective tissue capsule. The commonest sizes encountered are from one to three inches in diameter. Cavities less than one inch in diameter are usually difficult of recognition, either because they are deeply seated within the infiltrated lung or because they contain little air or have no definite capsule. Again, larger cavities may not be recognized if they are full of secretion and, therefore, cast a dense shadow indistinguish-

able from the infiltrated lung in which they lie. Occasionally the outlines of several cavities may overlap. Tuberculous cavities do not usually have the punched-out appearance commonly found in abscess of the lung nor do they usually show a fluid level. If at all, fluid is seen only in the larger ones. Cavities are most commonly found in the upper lobes and only rarely at the bases. The shadows in an infiltrated lung frequently give rise to deceptive appearances by enclosing circular spaces which may simulate cavities. Confusion may also arise at the hilum of the lung from the cross section of the larger bronchi and the spaces enclosed by branching blood vessels.

Tuberculosis of the Bronchial Nodes and Hilum.—In most adults, as a result of respiratory infection, tuberculous or otherwise, or of dust inhalation, the bronchial lymph nodes are enlarged and indurated and may contain lime deposits. The lung tissue between the nodes is also frequently thickened. These changes are readily noted on the plate. At times we can distinguish an enlargement of the various groups of nodes such as the paratracheal, the bifurcated, the bronchial or the bronchopulmonary. These changes at the roots of the lungs have little value in diagnosis as they are found in the majority of adults who are apparently well. The plate cannot determine whether these enlarged nodes are actively diseased and therefore responsible for the patient's symptoms at the time.

The term hilum tuberculosis should be reserved for the cases in which the disease begins at the root of the lung and extends outward into it. The diagnosis should only be made if the root structures are extensively infiltrated. Cases of anthracosis, emphysema or chronic bronchitis may result in the same modification of the hilum shadows as this form of tuberculosis.

Miliary Tuberculosis.—Miliary tubercles, when solitary,

are too small to give visible shadows. When they are closely studded, however, as in general miliary tuberculosis, groups of tubercles will cast shadows which can be recognized as infiltrations. They are about two to three millimeters in diameter and, in their early stages, are so indistinct as to give the lung a uniformly mottled appearance. A few days or a week after their first discovery they are more distinct and the appearance is unmistakable. The density of the shadows diminishes from the apex to the base. The plate reveals their presence long before they produce definite physical signs and, for this reason, is of decisive value in some cases of obscure disease. Tuberculous bronchopneumonia may assume a miliary form which may closely simulate general miliary tuberculosis. In the former, however, the infiltrations are more sharply outlined, are apt to be arranged along the course of the lung markings, and there is evidence of an older process in the upper lobe.

Activity.—Activity cannot be determined from an x-ray examination. We do know, however, that a great amount of fibroid tissue in a given lesion indicates chronicity. What we cannot determine is a lighting up of an active process in an old lesion. We must remember that the plate only shows anatomical changes and, while certain deductions can be made, they do not coincide necessarily with the clinical signs. After all, tuberculosis is a clinical disease, and we form our opinions of activity upon the general condition of the patient, namely, fever, weakness, loss of weight, cough, tubercle bacilli, râles, etc. None of these important manifestations can be determined by the x-ray examination.

The x-ray examination shows the extent of the lesion more accurately than the physical, but to obtain the best results a combination of the clinical and x-ray examinations is the ideal method.

Pneumonia.—In lobar pneumonia there is seen a uniform shadow coextensive with one or more lobes of the lung. In the early stages this shadow may be very faint. In the case of the upper lobe, especially on the right side, this shadow is usually somewhat denser and is sharply limited by the interlobar fissure. The shadow cast by a lower lobe pneumonia often appears smaller than would be expected, so that its upper border may extend only a short distance above the diaphragm. The whole lobe is not necessarily involved, or it may not be uniformly consolidated. The diaphragm is clearly visible below the infiltration, although its movement may be retarded. The infiltration may persist far into the period of convalescence, so that the examination may disclose shadows when physical signs are no longer present. The recession of a pneumonic process apparently may proceed in an irregular way. As a result the examination may show clearer areas within the infiltration, which may be confused with abscess cavities. Lobular and bronchopneumonia in the great majority of cases do not cast appreciable shadows. A tuberculous pneumonia, especially in the upper lobe, may cast a shadow indistinguishable from that of an ordinary pneumonia. Here the diagnosis must wait on the clinical history and the sequel. Postpneumonic empyema can be recognized at an early stage. The diaphragm in its outer portion becomes obscured, and the costophrenic sinus is occupied by a shadow which is denser than that of the neighboring lung.

In cases of persistent pneumonia with induration of the lung, the condition can be accurately studied. As a result of the formation of fibrous tissue, the shadows become much denser and, if large bronchiectatic cavities result, these can be observed on the plate.

Streptococcic bronchopneumonia frequently produces shadows on the x-ray plate difficult to differentiate from

those of tuberculosis. The entire lung field may be dotted with small distinct shadows similar to those seen in miliary tuberculosis. Again, there may be larger and irregular shadows in the parenchyma, some faint and others rather distinct, like those produced by conglomerate tubercles or multiple tuberculous foci. The streptococcic bronchopneumonias are often associated with localized empyemata and gradually clear up under several months' observation, which is not true of tuberculosis.

Diseases of the Pleura—

Pleurisy.—The diagnosis of dry pleurisy is usually difficult. A thin plastic exudate may not sufficiently intercept the rays to produce a perceptible shadow. Only at times does one see at the bases coarse linear shadows produced by denser exudates. On the screen there is noted a restriction or absence of diaphragmatic movement on the affected side.

In chronic tuberculosis and in cases of pleuropneumonia the thick pleura may produce a very dense homogeneous shadow of wide extent entirely obliterating the lung markings. The diaphragm is usually invisible and it may be difficult to distinguish this condition from that of a large pleural effusion. A retraction of the chest wall and displacement of the heart and mediastinum towards the affected side will render the diagnosis of pleural thickening more probable.

Pleural Effusions.—The shadows cast by pleural effusions are readily recognized by their usual location in the axillary portion of the chest. When small, they produce a dense uniform shadow at the base of the axilla which fills up the costophrenic sinus and obscures the outline of the diaphragm in its outermost portion. At this stage the level of the fluid is concave upwards. As the fluid increases this shadow rises until it may reach the apex occupying the entire chest. Even in such large effusions, however, the

compressed and airless lung may be seen indistinctly near the upper mediastinum. In larger effusions the upper level may become straight or convex upwards and is indistinct; the diaphragm is invisible.

On fluoroscopic examination the level of the fluid may show a slight shifting. This, however, is not as marked as is commonly supposed and takes place slowly, probably due to conditions which interfere with the free movement of the fluid.

The sequence above described is that commonly seen in the chest of adults. In young individuals, an effusion may have its beginning as a thin layer of fluid which extends along the periphery of the lung from apex to base. This is represented on the plate by a narrow shadow of uniform width, in the axillary portion of the chest reaching from the summit to the base of the lung. As the fluid accumulates the lung is no longer able to support it, and it gravitates to the bottom of the chest. It then assumes the appearance above described for adults.

The secondary changes in the chest resulting from pleural effusions are variable. While displacement of the heart and mediastinum are often noted, there may be none even with large effusions. On the other hand, a beginning pleurisy may cause displacement of the heart. Nor is the freedom or encapsulation of the fluid the determining element, as walled-off effusions may displace the heart to the opposite side.

Pleural effusions are frequently encapsulated by adhesions and the resulting shadows may be atypical. It is difficult to describe their many varieties. An encapsulated effusion most often occupies the axillary portion of the chest, and in one of its common forms is sharply bounded mesially and set off from the compressed lung. Its outline may suggest a sacculation into two or more compart-

ments. As most of them extend to the base, the diaphragm may be partly or wholly obscured. Occasionally an effusion may be localized over an upper lobe and simulate a pneumonic consolidation. Here a definite diagnosis may not be possible.

Interlobar effusions are not very common. Cases thus diagnosed clinically are more often examples of encapsulated effusions in the general pleural cavity. The commonest and most easily recognized occupies the upper right interlobar fissure. It may be combined with a general or encapsulated effusion. It appears as a homogeneous shadow, usually triangular in shape, traversing the chest horizontally at the level of the fissure. In width it is less than that of an intercostal space, the shadow being greatest and most distinct near the axilla. The oblique positions are helpful in this examination.

An uncommon form of encapsulated effusion is the so-called mediastinal pleurisy, in which the fluid occupies the mesial portion of the chest, lying close to the mediastinum. The shadow here is confluent with that of the heart.

X-ray examination furnishes little distinction between a serous, purulent or hemorrhagic exudate.

Pneumothorax and Hydro- or Pyopneumothorax.—A moderate degree of pneumothorax reveals the edge of the partly retracted lung a variable distance from the chest-wall, the space previously occupied by it showing an absence of lung markings. With an increase in the amount of air in the pleural cavity the lung is crowded upward and inward to the spine, and, with marked positive pressure, may even be displaced together with the mediastinum into the opposite chest. In extreme cases the edge of the mediastinum may present in the opposite chest a curved linear shadow with its convexity outward. Frequently such a complete pneumothorax is prevented by adhesions which

may immobilize any portion of the lung. The location and character of these adhesions can be readily determined on the plate. The pneumothorax, if of large extent, may depress the diaphragm and interfere with its movements. The soft tissues of the neck and thorax should always be examined to determine the presence of subcutaneous emphysema.

Whenever air and fluid are simultaneously present in the chest the latter acquires a horizontal level. This fact is of importance in diagnosis, as the presence of such a level in the chest, if not due to a cavity in the lung, always indicates air in the pleural cavity. It is, thus, frequently noted in cases of pleural effusion in which incomplete aspiration has been performed and a small amount of air accidentally introduced. It portrays faithfully any number of sacculations in a case of hydro or pyopneumothorax with adhesions in which each pocket of pus has its fluid level with a bubble of air above it, the former shifting immediately on change of position unlike effusions without air.

The examination is indispensable to the proper performance of artificial pneumothorax in pulmonary tuberculosis. It determines whether air is actually introduced, whether it has passed into the pleural cavity or into the subcutaneous tissues or under the diaphragm. It may disclose the cause of failure of the operation, such as pleural adhesions. These it localizes, determines their size and apparent strength and whether they are apt to be reduced. Finally the examination will indicate when the pneumothorax is complete and the degree of mediastinal displacement.

The examination is also of value in the study of pneumothorax following operation for empyema. Here one can accurately note the size and shape of the sinus, the presence of retained pus and the efficiency of the drainage.

The Diaphragm.—The shape and position of the normal diaphragm are subject to considerable variation, depending on the shape of the thorax. Thus, in broad-chested individuals it is higher in position and its convexity is greater. In the asthenic type of chest it is depressed and flatter in contour. The costophrenic sinus should be sharp and clear and should increase in width and depth on deep breathing.

The contour of the diaphragm is usually smooth. Occasionally, on deep breathing, owing to irregular contraction of its muscular bundles, its outline may be broken up into several smaller convex curves. These must not be confused with pleural adhesions or with subdiaphragmatic conditions. Pleural adhesions give rise to fine-pointed projections on its surface. If these adhesions are broad they may produce only an indistinctness in its outline. A common evidence of old pleurisy is an obliteration of the costophrenic sinus by adhesions.

The position of the diaphragm is often an indication of disease of the structures in its vicinity. In cases of dry pleurisy and lobar pneumonia it is usually slightly elevated. The dome of the diaphragm may reach an extreme height in the chest in cases of ascites, gaseous distension or abdominal tumor. A subphrenic abscess may cause a unilateral elevation of the diaphragm. If this is of slight degree, it is difficult to distinguish from a pleurisy. The diagnosis of a subphrenic abscess is only warranted if the upward displacement of the diaphragm is considerable. A subdiaphragmatic gas abscess, especially on the right side, produces a characteristic picture of a fluid level under the right diaphragm surmounted by a crescentic bubble of air. The fluid shifts on change of position.

Eventration of the diaphragm and diaphragmatic hernia produce a similar appearance. The thinned-out and atro-

phic diaphragm is pushed high up into the chest by the distended viscera below it, at times extending to the level of the second rib. Eventration of the diaphragm usually occurring on the left side, there is commonly a marked displacement of the heart to the right so that a condition of dextrocardia is closely simulated. Occasionally, tumors of the liver may produce a local prominence on the dome of the diaphragm. This must not be confused with muscular contractions.

The movement of the diaphragm must be studied with the screen. It varies in extent according to the predominance of costal or diaphragmatic breathing. In many cases of incipient tuberculosis the diaphragm on the affected side is restricted or even inhibited in its contractions. This may occur independently of any adhesions. It is very common in advanced, especially fibroid tuberculosis. In lobar pneumonia a paretic diaphragm may persist far into convalescence. Adhesions may affect the movement of the whole or part of the diaphragm. Thus pericardial adhesions may cause a lagging of only its mesial portion. The so-called paradoxical movement of the diaphragm occurs in cases of large pneumothorax and in eventration, the movement being in the opposite direction from the physiological. Complete paralysis may be observed in bulbar palsy or in poliomyelitis and after operative section of the phrenic nerve.

Lung Abscess and Bronchiectasis.—From an x-ray standpoint it is in most cases not possible to distinguish between abscesses which arise from dilated bronchi and those which have developed from an immediate breaking down of lung tissue. Such a diagnosis must depend to a great extent on the clinical history and probable etiology of a given case. The term gangrene of the lung does not represent a distinct entity except in some acute cases. It is a descrip-

tive term pointing clinically to the existence of putrid sputum which is present at some time or other during the course of most cases of suppuration without apparently affecting the course of the disease.

The more common causes of lung suppuration are:

1. Pneumonia and influenza.

2. Aspiration of foreign, especially septic, material during operations under general anesthesia.

3. Accidental aspiration of foreign bodies, especially in children.

4. Fibroid conditions of the lung, whether due to syphilis, tuberculosis, or other chronic forms of pneumonia.

Old cases of encapsulated empyema are often disguised clinically as cases of lung abscess.

Two essential pathological changes are present in practically all cases of lung suppuration. In the first place there is an infiltration or consolidation of the lung of varying extent. Secondly, imbedded in the infiltrated lung are one or more cavities. These may be multiple, bronchiectatic dilatations, or a small number of irregular necrotic cavities.

The examination, therefore, has for its object the demonstration of a pulmonary infiltration or of a cavity in the lung, or both, and there are few thoracic conditions in which it is more instructive. In abscess of the lung the symptoms, such as expectoration of the characteristic sputum, take precedence over the physical signs which are usually not pronounced. It is almost the exception to elicit the physical signs of a cavity, because the cavity is usually imbedded in the infiltrated lung. The infiltration, on the other hand, often gives no signs because it may be scattered or of small extent or masked by aerated lung.

A typical form of lung abscess is that due to aspiration.

The findings vary depending on the evolution of the process. In the early weeks after the onset, there is often considerable pneumonic infiltration which may involve a whole lobe or a part of it, the shadow being usually denser than that of lobar pneumonia. At even this early stage of the disease a cavity varying from ½ to 1½ inches in diameter can usually be demonstrated within the infiltrated area.

One must, however, be prepared to make the diagnosis of lung abscess although a cavity is not shown on the plate. In a case presenting the history and symptoms of lung suppuration, the discovery of a pneumonic infiltration will warrant the diagnosis. It may occur in any of the lobes and may be so small in extent as to be barely visible. This occurs especially during a period of either temporary or permanent improvement. As the disease progresses repeated examinations will often show an increase in the extent and density of the shadows, thus making absolute what was previously a doubtful diagnosis.

Abscess Cavities.—The term abscess of the lung naturally brings to the mind the notion of a cavity within it. While a section of the lung would in every case show one or more cavities, the x-rays will disclose them only when they are sufficiently large, favorably situated, and partly filled with fluid. Abscess cavities have, as a rule, a punched-out appearance due to the contrast between the air in them and the dense lung about them. As they are usually partially filled with fluid, they show, in the upright position, a horizontal level which is surmounted by air, an appearance which is pathognomonic. At times the fluid level is seen without other evidence of a cavity. The fluid level shifts on change of position, and the size and shape of the cavity in the vertical diameter may be determined.

Cavities are nearly always circular. In most cases only one is seen, especially when it is large. Of the smaller

ones several may be noted grouped together in one region. The plate rarely shows a distinct capsule about them, except in the very old ones. In these cases it is unusual to

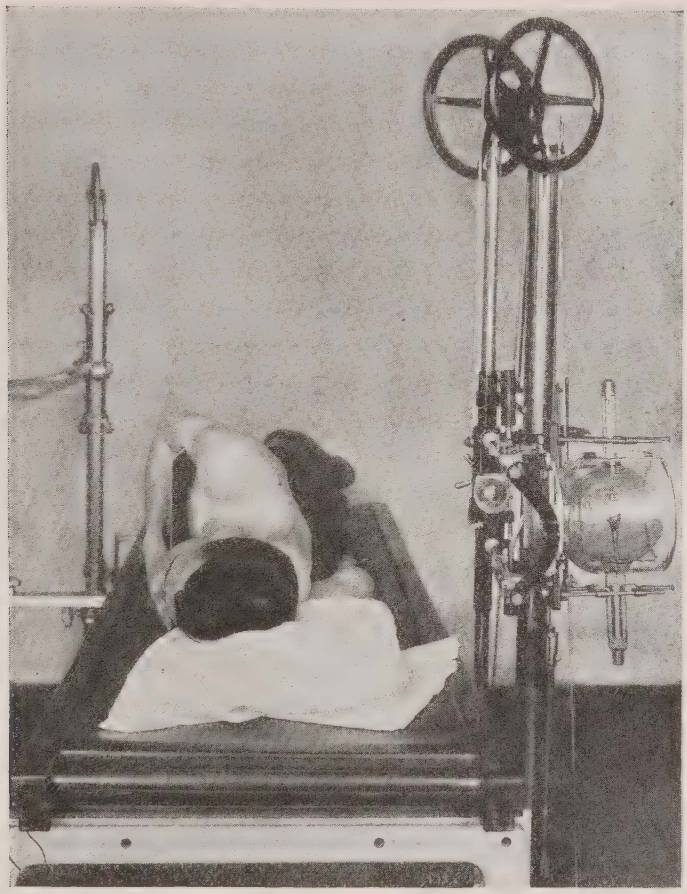


FIG. 180. Lateral recumbent position.
Especially useful for the demonstration of shifting fluid levels. Good method to demonstrate abscess cavity.
The affected side should be uppermost; the focus of tube, as nearly as can be determined, opposite area of lesion. The patient can hold the plate himself (shown in this illustration) or the plate may be held against his chest by the screen carrier. Direction of rays need not be always dorsoventral, as shown in this illustration, but may be ventrodorsal, depending upon what is most desirable in a given case.

find them surrounded by dense layers of connective tissue as is seen in old tuberculous cavities.

The absence of a cavity in a presumed case of pulmonary

suppuration should not be affirmed from a single examination. A cavity full to repletion may cast a shadow indistinguishable from the surrounding infiltration. A later examination after expectoration may reveal it partly empty. It is remarkable with what fidelity a good plate will mirror forth even the faintest level of fluid in an abscess cavity. The cavity may be situated deep down in the costophrenic sinus or be partly hidden by the heart. In these cases examination in the lateral recumbent position (Fig. 180) may have to be resorted to. A cavity not seen in the ordinary dorsoventral position may occasionally be visible in the ventrodorsal or in one of the oblique positions. Doubtless the smaller and deeper ones will elude the most careful examination.

Another type of suppurative lung disease is that resulting from the various forms of indurative pneumonia, usually of long standing, in which there is a formation of multiple small bronchiectases. Although larger bronchiectatic cavities may develop, usually they are too small to be noted on the plate. Under the circumstances diagnosis must be made from the presence of an infiltration, which is often lobar in distribution, very dense and usually situated in the lower lobes. At times when they are empty, the numerous small bronchiectases will give to the lung a honeycomb appearance. These cases are often assumed clinically to be chronic bronchitis, tuberculosis or persistent pneumonia. The clinical history, together with the x-ray findings of a pneumonic process, will show them to be chronic nontuberculous bronchiectases.

Repeated examinations will throw light on some of the changes which are taking place in the lung during the evolution of abscess. Exacerbation in the fever and cough may be seen to be coincident with an increase in the area of pneumonic consolidation. Or, as the result of the over-

flow of the secretion of a cavity, a septic bronchopneumonia of a lower lobe may rapidly develop. The changes in the size and contents of the cavities can be noted.

Abscess of the lung is subject to deceptive remissions, and these slight infiltrations become the starting points for renewed infection. The marked thoracic deformity and displacement of the heart and mediastinum so commonly seen in tuberculosis are absent in abscess.

The x-ray examination is of great value to the surgeon. In the first place it determines the location of the process, which must precede any surgical intervention. On this and on the extent of the disease will depend the type of operation to be performed. The size and position of the cavity with respect to the chest wall will often decide whether the operation shall consist merely of incision and drainage, which at best is only palliative in most cases, or whether an actual lobectomy is advisable. The presence or absence of pleural adhesions may sometimes be ascertained. After operation the examination is of no less importance. It will indicate the success of the drainage or the completeness of the removal of the diseased lobe. It is also a guide to the success of measures adopted for the obliteration of the dead space produced by the operation.

Differential Diagnosis.—It is not necessary to go into a differential diagnosis between the appearance of lung abscess and other thoracic conditions with which it might be confused. The clinical history will usually serve to distinguish them. There is, however, at times some difficulty in differentiating abscess from tuberculosis. The following points of distinction are suggested, although they will not always apply. An infiltration or a cavity in a lower lobe with no coincident process in the apex is probably not tuberculous. In cases of upper lobe infiltration the difficulty may be greater. Homogeneous consolidations of the

lobar type are more apt to be abscesses, especially if they contain a cavity with a fluid level. The coarse bands of connective tissue, extending to the hilum, and calcareous deposits, so frequently found in chronic tuberculosis, are rare in abscess.

Tuberculous cavities are, as a rule, different in appearance from abscess cavities. They usually contain no fluid. Tuberculous cavities occur usually in the upper lobe and are uncommon at the bases. Of course, tuberculous cavities may be secondarily infected. In that case, they are to all intents and purposes abscess cavities and cannot be distinguished from them, except perhaps by the character of the surrounding infiltration. Old cases of encapsulated empyema are frequently mistaken clinically for lung abscess.

New Growths of the Lungs.—New growths of the lungs may be divided into two types, metastatic and primary.

Of metastatic new growths those most commonly encountered are carcinoma and sarcoma. By means of the x-ray examination alone it is not possible to distinguish them. The earliest metastases appear as faint circular homogeneous shadows a few millimeters in diameter. They are irregularly distributed throughout the lungs and are larger in the lower lobes. The size they attain varies with the type of the primary tumor and the duration of the disease. They may attain the size of a lobe; on the other hand, even at a late stage of the disease the lungs may be studded with myriads of small metastases. Miliary carcinosis may be difficult to differentiate from some forms of tuberculosis. The x-ray examination will reveal metastases before the clinical examination will discover them. For this reason it is important to ray the chest prior to operation of primary tumor, especially sarcoma, in other parts of the body.

Primary new growths occur in two forms, the true pul-

monary and the mediastinal tumors. By the x-ray examination, just as by the clinical, it is often impossible to decide whether a neoplasm arises in the lung or mediastinum, because mediastinal growths as they increase in size may invade the lung. In their earlier stage this distinction may be made.

Primary carcinoma of the lung assumes two forms, the so-called bronchial carcinoma and the lobar carcinoma. The former begins usually in one of the larger bronchi and casts a dense shadow extending a variable distance from the root of the lung. Numerous secondary tumors develop by extension along the bronchial system, producing a network of small shadows along the bronchial tree. In lobar carcinoma there is found a dense shadow which occupies a part or all of a lobe. This seems to occur more frequently in the upper lobes. In all forms of primary growths the intercostal spaces are frequently narrowed, and the heart and mediastinum are apt to be drawn over to the affected side, unless prevented by a hydrothorax.

It should be remembered in the diagnosis of pulmonary neoplasms that the shadows have not a typical arrangement, as in tuberculosis and, therefore, in order to avoid error, the clinical data should be fully utilized. Not uncommonly a neoplasm is completely masked by a pleural effusion, so that a diagnosis cannot be made until after aspiration of the chest.

Mediastinal New Growths.—Under this heading are included the various lymphomata, Hodgkin's disease, lymphosarcoma, and carcinoma and sarcoma. Only to a limited extent is it possible to distinguish these from each other.

The masses of enlarged lymph nodes in Hodgkin's disease produce rather faint shadows at the roots of the lungs. These extend a variable distance into the pulmonary tissue.

Usually the shadow has an irregularly lobulated border which is well demarcated. At times small secondary nodules are seen elsewhere in the lungs.

In the other varieties of new growths a dense shadow extends outward from the mediastinum, usually on both sides. This shadow is confluent with that of the heart and of the aorta, although on the fluoroscope it can usually be distinguished from it. It may occupy only the upper mediastinum, as in the case of a substernal thyroid, or only the region of the hilum of the lungs. Its outline may be smooth or lobulated, straight or convex. The shadow is homogeneous and shows no calcareous areas as in tuberculosis. Occasionally the growth can be seen radiating in all directions into the lung tissue. Small outlying metastases may also be seen in the lung. In the oblique position the relation of the growth to the trachea and esophagus can be studied, and pressure by the growth on these structures, or their invasion by it, observed. In the dorsoventral position a narrowing of the caliber of the trachea may be seen or a downward or lateral displacement of the arch of the aorta. On fluoroscopic examination, in the case of compression of a large bronchus, the so-called bronchostenotic sign may be observed. This consists in a displacement of the mediastinum toward the side of the stenosis on deep inspiration. Mediastinal growths favorably placed with regard to the heart or the aorta will show a transmitted pulsation. This is very difficult to distinguish from that of a pulsating aneurysm and, for this reason, has little value in a differential diagnosis.

In conclusion, it should be emphasized that it is hazardous to venture a diagnosis of mediastinal growth solely on the basis of moderate enlargement of the hilum structures. Such a condition is, in the vast majority of cases, due to

the enlargement of the bronchial lymph nodes, regularly found in adults.

Tumors of the ribs and spine occasionally cast shadows in the chest which must be distinguished from intrathoracic conditions. Thus, rib sarcomata may produce circumscribed shadows of uniform density, which may simulate pulmonary new growths, or, if they occur near the periphery of the chest, may resemble encapsulated effusions. Careful study of the rib structure, sometimes in the oblique position, or stereoscopy will reveal an absence of the rib at the site of the shadow. Pott's abscess of the vertebræ must occasionally be taken into consideration in the interpretation of intrathoracic shadows.

Aneurysm of the Thoracic Aorta.—In the diagnosis of aortic aneurysm the x-ray is recognized by the clinician as the most valuable method of examination. Fluoroscopy is far superior to radiography because we are dealing with an organ in motion. The plate merely furnishes a permanent and graphic record for comparison with later examinations. The patient should be fluoroscoped in several directions. The dorsoventral position furnishes the most information. The first oblique position shows the encroachment upon the posterior mediastinum by an aneurysm of the descending aorta; the second oblique position brings out more clearly an aneurysm in the ascending aorta and may show the extent of an aneurysm of the descending aorta. A true lateral view, which is feasible in a small number of cases only, is of value in determining the anteroposterior enlargement of the aorta.

Though pulsation is not an absolutely reliable sign in all cases, its presence or absence, its character, whether expansile or transmitted, will aid in the diagnosis. Expansile pulsation (pulsation in all directions) suggests aneurysm, especially of the fusiform variety. Transmitted pulsation

(pulsation in one direction) occurs when a mediastinal tumor is in close contact with the aorta. In this condition the excursions of the aorta move the tumor, thus giving the appearance of pulsation. On the other hand, very slight pulsation or even its complete absence does not exclude aneurysm. This is especially true of the sacculated variety on account of the thickening of the sac.

Aneurysms may involve any portion of the aorta, but in their order of frequency are seen as follows:

1. Aneurysms of the ascending aorta cast their shadows almost entirely to the right of the spine and lie near the anterior chest wall.

2. Aneurysms of the arch lie in the upper part of the mediastinum, generally in the midline, but may extend to the right or left according to the portion of the arch that is involved. They also are nearer the anterior chest wall.

3. Aneurysms of the descending aorta are almost entirely to the left of the midline and lie nearer the posterior wall.

The shadow of the aneurysm is of necessity confluent with that of the aorta. It is even in contour, rather convex and usually shows no lobulations.

The shadow cast by an aneurysm of the ascending aorta and arch is as dense as that of the heart, because both are situated in the same vertical plane. The shadow cast by an aneurysm of the descending aorta is less dense in the dorsoventral position because it is not in the same vertical plane as that of the heart shadow, being situated more dorsally.

The large aneurysms are usually fusiform. The smaller ones are either sacculated or fusiform. As a general rule, those of the arch are more frequently sacculated; those of the descending and, to a lesser extent, those of the ascending, are more frequently of the fusiform variety. It

is important to remember, however, that there are dilatations of the aorta which are not aneurysms in the true sense of the word. This fact must be borne in mind when examining adults beyond middle age, because in them a moderate enlargement and lengthening of the aorta are common. This is shown usually by an increased prominence in the upper part of the chest to the left of the spine, as the aorta turns downward and backward. In cases of atheroma, the aorta may be uniformly dilated throughout its entire course. In such cases it extends to the right of the sternum, the arch is prominent and the descending portion may be seen as a faint shadow to the left of the spine. This condition is frequently associated with hypertrophy of the left ventricle and aortic insufficiency. On the other hand, enlargement of the heart is generally not associated with aneurysm.

The most common difficulty encountered is the differentiation between aneurysm and mediastinal tumors. The following points may be helpful:

The shadow caused by an aneurysm is usually denser than that of a tumor.

Large aneurysms of the aorta, especially of the first portion, displace the heart downward and often to the left. Tumors nearly always displace the heart laterally.

Large aneurysms of the arch and descending aorta displace the trachea and esophagus, while tumors, except intrathoracic thyroid, envelop them.

Fluoroscopy in the oblique positions will help to establish the relation of the aneurysm to the heart, aorta and the other thoracic organs, which cannot otherwise be done. In this manner, we can sometimes recognize the normal contour of the aorta within a shadow which is suspicious of aneurysm and thus establish the diagnosis of tumor rather than of aneurysm.

Growth of the aneurysm may produce changes in the adjacent viscera or in the spine. These changes are entirely mechanical and due to pressure.

Pressure upon the esophagus may cause displacement and obstruction, which is at times almost complete. In case an aneurysm is very large, it is advisable to examine the esophagus with the aid of a barium mixture so as to determine the presence of esophageal obstruction, or compression. Often the fluoroscope would show pressure upon the esophagus long before the patient noticed difficulty in swallowing.

Pressure upon a bronchus may cause bronchostenosis or even atelectasis. In such cases the fluoroscope shows in the lung field supplied by the bronchus a darker area which does not become lighter upon deep inspiration. Occasionally the severe spinal symptoms associated with aneurysm are due to actual erosion of one or more vertebræ from pressure.

X-Ray Examination of the Heart.—The method of choice in the roentgen study of the heart is fluoroscopy. The reason for this is that the heart is an organ in continual motion, and a study of its movement is essential to a proper interpretation of the shadows. The plate gives such a distorted image of the heart that it is not only valueless but may give rise to entirely erroneous deductions. Of all the methods, orthodiagraphy, combining as it does direct observation and a true graphic image of the heart, is most valuable. A plate made at a distance of six feet (teleroentgenogram), although not as serviceable, is of value for determining heart size.

The cardiovascular shadow is composed of a number of curves, two on the right side and three or four on the left, which represent the following parts:

The right upper curve represents superior cava or, occasionally, the ascending aorta.

The right lower curve represents the right auricle.

The left upper curve represents the arch of the aorta.

The left middle curve represents the pulmonary artery.

The left lower curve represents the left ventricle.

Occasionally the curve of the left auricle is seen between the middle and lower curves. (Fig. 181.)

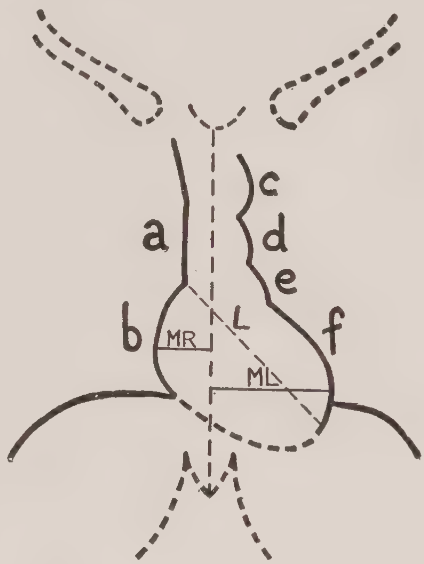


FIG. 181. Normal heart (or thodiogram).

(a) Vena cava superior. (b) Right auricle. (c) Descending arch of aorta. (d) Pulmonary artery. (e) Left auricle (occasionally seen). (f) Left ventricle. The right ventricle is never seen in this position.

MR—Longest distance between the median line and the right border. *ML*—Longest distance between the median line and the left border. *L*—Longitudinal diameter. $ML + MR$ equals the transverse diameter, T.

The shape and extent of these shadows which form the contour of the heart are more or less constant though they are subject to slight physiological variations. At times these shadows are ill-defined and a study of their pulsations may be necessary to distinguish them. The latter differ both as to their amplitude and their time phase. Thus the right lower curve of the auricle shows a very faint pulsation presystolic in time. The curve of the left ventricle has the widest pulsation systolic in time. The aortic and pulmonary curves show a moderate expansion synchronous with the contraction of the ventricles. The left auricular appendage is poorly seen the ordinary position and shows only a slight presytolic undulation.

Normal Variations of the Heart Shadow.—The configuration of the heart shadow is determined to a considerable extent by the obliquity of its long axis. But this is frequently affected by extrinsic factors. Thus it will vary with the type of the thorax, being more horizontal in the broad-chested and more oblique or vertical in the narrow-chested or asthenic individual. Adiposity or gaseous distention of the intestines may rotate the heart into a more horizontal position and may mold it so that it will simulate a hypertrophy. In the aged the heart is less oblique in position and its apex becomes blunted. There is some variation in the prominence of the individual curves. The pulmonary artery is at times abnormally large without any evidence of cardiac disease. The arch of the aorta, especially in persons beyond the age of forty, is frequently prominent, and this should not be looked upon as evidence of serious disease. It is, therefore, important in estimating the significance of a particular cardiogram to keep in mind these normal variations.

Heart Size.—By means of the x-ray approximate figures of the heart size have been determined in a large number of healthy individuals. These have been formulated in standard tables.

The dimensions most commonly used are conveniently designated by the values ML and MR, indicating respectively the greatest distance of the left and right borders from the midline. The sum of these two values represents the width or transverse diameter of the heart, T. A third dimension, L, representing the longitudinal diameter is also frequently used. It extends from the angle formed by the right auricle and vessels to the apex (Fig. 182). A study of tables shows that the size of the heart varies with the height and weight of the individual and also with the sex, the figures for the female being slightly smaller. In

a general way the relation of MR: ML is as 1: 2. In applying these tables, the height of the individual must be determined and the dimensions of the heart compared with the normal figures for a subject of the same height. In determining whether a given case exceeds the normal, a difference of ½ to 1 cm. in the transverse diameter from the normal is permitted.

NOTE.—At the end of this chapter the reader will find a detailed description of the method used by the cardiovascular service.

Dilatation and Hypertrophy of the Heart.—A dilatation of the cardiac cavities results in an increase in the size and prominence of the contour together with an increase in the values ML and MR. In the case of the left ventricle this results in a more horizontal position of the heart, so that it acquires a shape which has been compared to that of an egg. The ventricular border formes a sharp angle near the pulmonary curve and the apex is blunted. A dilatation of the right ventricle by itself produces no enlargement of the heart, but it changes its conformation by dilating in an upward direction, so that the conus arteriosus and its right auricular attachment are displaced upward. The heart thus acquires a more vertical and globular aspect. A marked enlargement to the right is usually due to a coincident dilatation of the right auricle. It is well to bear in mind, however, that whereas clincally a distinct increase in absolute heart dullness to the right may be found, the x-ray frequently in such cases shows the right heart border to be in its normal position.

A pure hypertrophy of the left ventricle is readily recognized. The silhouette is the same as described above in cases of dilatation of the left ventricle, except that there is no increase in the size of the heart. The pulsation is deliberate and of increased amplitude. The greatest en-

largement to the left is found in cases of aortic insufficiency, in the hypertensile form of chronic nephritis and in advanced mitral disease; enlargement to the right is most often found in all forms of decompensation and in congenital heart disease.

Displacement of the Heart.—This is readily recognized.

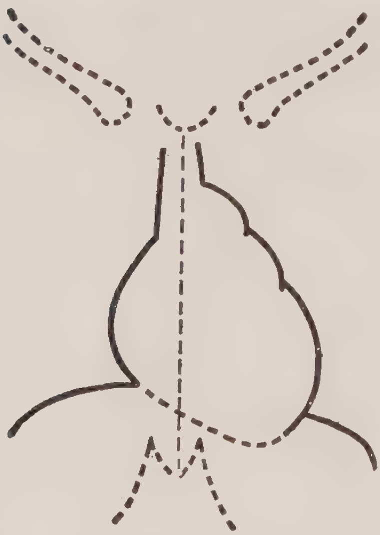


FIG. 182. Mitral insufficiency: Entire cardiac shadow enlarged (except right vena cava. The prominence of the pulmonary artery is not due to enlargement of the artery itself but to displacement by the enlarged heart.

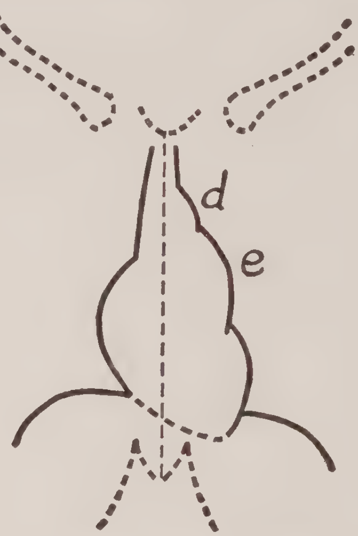


FIG. 183. Pure mitral stenosis: Marked enlargement of the left auricle (e). Heart otherwise not enlarged. Pulmonary artery (d) may be slightly enlarged. Aortic arch not shown on this sketch.

One of the most frequent causes is chronic tuberculosis in which the heart is usually drawn over by pleural or mediastinal adhesions to the side containing the oldest lesions. Pleural effusions frequently displace the heart to the opposite side. This, however, is not an invariable rule, as the heart may occasionally be in its normal position even in the presence of a large effusion. In kypho-scoliosis the heart is frequently displaced and rotated; on the other hand this does not invariably result, as the heart may be

normally situated in spite of marked thoracic deformity. In emphysema and asthma the heart is often hypoplastic and its apex depressed below the sixth interspace so that it acquires the shape of a drop heart. The most extreme displacement may be found in eventration of the diaphragm, so much, in fact, that a dextrocardia is closely simulated, when the eventration is on the left side, a more frequent position than on the right.

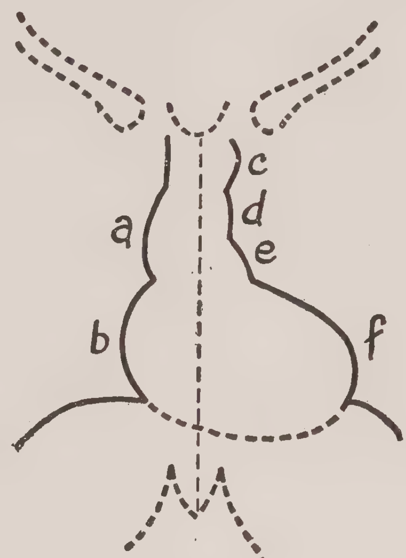


FIG. 184. Aortic insufficiency: Left ventricle (f) markedly enlarged. Left auricle (e) and pulmonary artery (d) little affected. Aortic arch (c) more prominent. (a) in this case, represents ascending aorta masking vena cava superior. (a) and (c) are actually enlarged in advanced stages. In the early stage they are more prominent because of the increased volume of blood they have to carry.

The transverse position of the heart is characteristic of this condition.

Valvular Lesions.—The mechanical changes produced by valvular lesions and the resulting alterations in the cardiac cavities are faithfully reflected in the heart shadow. Each cardiac lesion or its combination with others has a more or less characteristic silhouette. Some of these are represented in the accompanying figures. Figs. 182-184. Of particular importance is the recognition of the early stages of mitral disease. The earliest signs noted are a slight enlargement to the left, an increased prominence of the pulmonary artery and of the left auricle, and a tendency toward globular shape.

Nephritis and Arterial Hypertension.—In their early

stages these two conditions produce a hypertrophy of the left side of the heart with little or no dilatation. The appearance on the screen is characteristic. The heart is horizontal, egg-shaped, and is blunted at the apex. As these conditions are frequently combined with atheroma of the aorta, the latter is usually seen to be dilated and irregular in outline. (Fig. 185.) These cases are frequently confused with aneurysm, owing to pulsation of the aorta; this error can be avoided by noting the diffuse character of the aortic dilatation and the enlargement of the left ventrical. In the later stages of chronic nephritis we see evidence of failure of the left ventricle, namely, enlargement to the right and prominence of the left auricle and of the pulmonary artery. The amplitude of the pulsation as noted on the screen bears no relation to the amount of hypertrophy or dilatation nor to the muscular strength of the ventricle. The largest hearts may show practically no pulsation, and inferences as to cardiac failure should not be drawn from its absence.

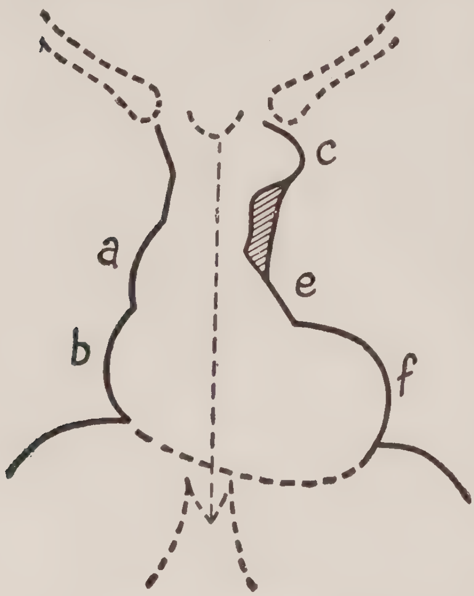


FIG. 185. Atheroma of the Aorta: (Arterial hypertension —chronic nephritis). Aortic arch (c) and ascending aorta (a) enlarged. Pulmonary artery not seen on account of actual dilatation of aorta to left (shaded area). In this illustration enlargement of heart is due to chronic nephritis.

While aortic dilatation is frequently associated with cardiac enlargement from various conditions, it may occur unaccompanied by heart changes in individuals beyond middle age. In young individuals, on the other hand, it is invariably associated with cardiac changes.

Angina Pectoris and Anginoid Pains.—Precordial pains.

anginoid in type, are found in a variety of heart and arterial conditions, the nature of which may be disclosed by the x-rays. In younger individuals they are usually found to be based on the valvular diseases, particularly aortic insufficiency. In the latter, especially when it is consecutive to syphilitic aortitis, the examination will show a slight dilatation of the aorta at its origin. In older persons, angina may be associated with atheroma of the aorta and arterial hypertension. The aorta is seen to be thickened, tortuous, and dilated throughout and frequently contains lime placques. A study of the ascending aorta in the second oblique position will reveal an enlargement of the conus arteriosus.

A large group of cases of angina pectoris in adults is primarily due to sclerosis or thrombosis of the coronary artery. There is no change in the size or shape of the heart, and the aorta is little, if at all, dilated. In these cases the examination has only a negative diagnostic value in excluding the conditions previously mentioned. It is important to emphasize that in these cases there may be an infarction of the heart muscle with extreme fatty and fibrous degeneration, but with no evidence of enlargement of the heart even shortly before a fatal termination.

So-called Functional Heart Disease.—There is a fairly large number of individuals in whom systolic murmurs at the apex of the heart are heard and in whom no other evidence of heart disease is found. The question will always arise whether these persons have valvular lesions or whether the murmurs are so-called functional or accidental ones. In such cases, the most important factor to determine is an enlargement of the heart. Examination may be of decisive value in these cases. In a case of such a doubtful heart murmur, if no enlargement of the heart or change in

its configuration are shown, it may be fair to assume that the murmur is not valvular in origin.

In a similar way we may have recourse to the x-ray in a study of the various functional disturbances resulting from excessive work or nervous excitement incidental to a soldier's life. The marked cardiac over-action in these cases makes accurate percussion difficult, and frequently gives the impression of an enlargement of the heart. This enlargement is only apparent and is due to the so-called irradiation of the apical impulse. Whatever the mechanism of the cardiac weakness in these cases, the x-ray examination shows that it is not due to a dilatation of the heart. On the contrary, the asthenic individuals who are especially prone to these functional disorders under stress frequently have hypoplastic or drop hearts (Fig. 186).

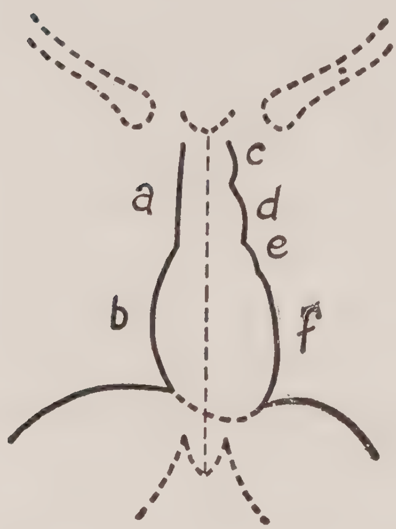


FIG. 186. Drop heart.

Drop heart occurs in long chested, thin individuals and in chronic wasting diseases. In the latter it is merely due to the general undernourishment of the individual and not to any disease of the heart itself. Drop heart occurs frequently in the later stages of tuberculosis and, at one time, was erroneously considered as pathognomonic of tuberculosis and even as a predisposing factor in this disease.

Heart Function.—Little, if any, deduction of value as to the function of the heart muscle can be drawn from the x-ray examination. The amplitude of contraction of the left ventricle is no index of its muscular power. Nor-

mally two types of contraction may be seen, a strong and a weak. The former is commonly noted in nervous or erethic individuals and in the asthenic or drop heart. The latter is noted in subjects who are less influenced by the excitement induced by the novel examination. Fluoroscopic tests of function have been barren of results. The heart in all individuals reacts to muscular work by a decrease in its size, which is closely related to the degree of tachycardia. The heart responds in a similar manner to a change from the recumbent to the upright position. Cases of organic disease react to these maneuvers pretty much as normal hearts do. As far as is known, dilatation of the heart after exertion cannot be used as a test of function, as it rarely if ever occurs under experimental conditions. Little change is noted in the size of the heart after treatment, even though there be marked improvement of the symptoms. In cases which show a marked recession of the cardiac borders after treatment the possibility of the resorption of a moderate pericardial effusion should be considered.

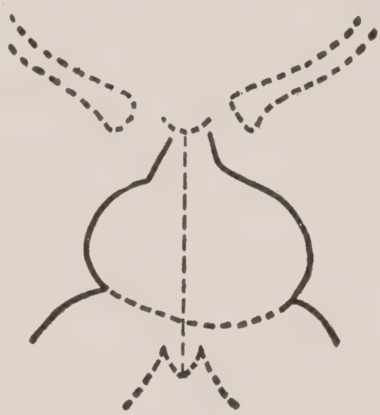


FIG. 187. Large pericardial effusion: Heart shadow is enlarged laterally and upward, encroaching upon aorta. Contour divisions are absent.

Pericarditis.—A pericardial effusion, if moderate in amount, results in a general increase in the size of the heart shadow. Under these conditions the diagnosis cannot be made. It is only when the pericardial sac is distended with fluid that it produces a characteristic appearance (Fig. 187). The heart assumes a flask shape and extends upward to the first or second rib and also into the right chest,

where it frequently occupies as much space as in the left. The heart contours are long; the pulsations are usually not visible, although occasionally a diffuse impulse may agitate the whole mass.

In advanced myocarditis the cardiac shadow is somewhat similar to that of pericardial effusion. The distinguishing features in this condition are that the cardiac silhouette is more triangular in shape, does not extend as much to the right, and does not encroach upon and obliterate the aortic shadow.

Adhesions between the pericardium and pleura are frequently seen as small pointed projections extending out to the surface of the heart. An obliteration of the pericardium can only be diagnosed if, in addition, there are pleuropericardial adhesions. Under these circumstances, on deep inspiration, with each contraction of the heart the left diaphragm may be pulled up forcibly. This corresponds to what is clinically known as Broadbent's sign.

Method of Heart Measurement.—(Adopted by the Cardiovascular Service.) Various attempts to correlate heart measurements with pathological conditions have been made. Considerable caution in this connection may be advised for two reasons: first, there is no very definite relation between the size of an organ and its functional condition; second, the errors due to unusual position of heart or bad apparatus adjustment are such as to make the measurements themselves somewhat uncertain.

At the Army Medical School a method is used at present, based on the tables of Dr. C. R. Bardeen. For this reason the tables and the following brief note as to the method are inserted.

The required radiograph is made as follows:

Patient standing with sternum flat against upright plate holder: target-plate distance, 6 feet; target level opposite

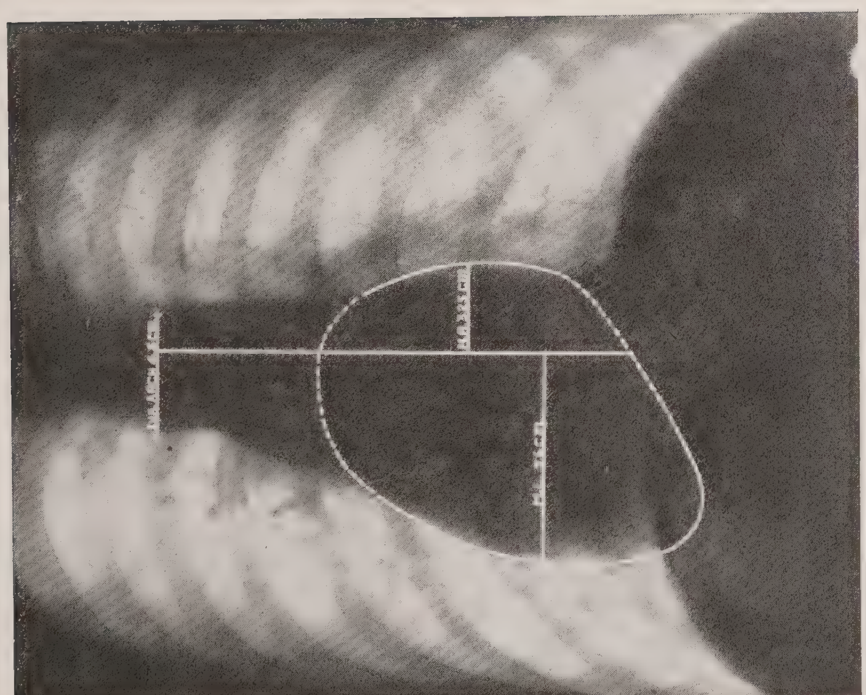


FIG. 188. Cardioroentgenogram of chest of a man, showing right and left margins of heart, which are clear in the negative. Upper and lower borders of heart arbitrarily sketched in dotted lines. The lines ML, MR, Dia Arch represent respective diameters.

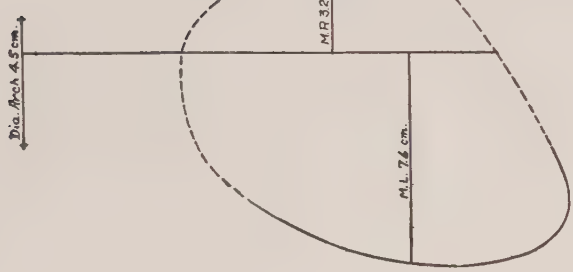


FIG. 189. Type of tracing furnished clinician with report. Underscored items are those of the observed patient. The other factors are obtained from Dr. Bardeen's tables.

NOTE:—this case represents a heart of normal size.

TABLE (Bardeen)

Table showing relations of a heart shadow area of a given size to approximate transverse diameter, body weight, heart weight, heart muscle weight, heart volume in diastole, and height for either sex, at a given age. Individual at rest, sitting.

Heart Silhouette Area	Approx. Trans. Diam.	Weight of Body		Weight Heart Empty	Volume Heart Diastole	Height at given age for given weight								
						20 yrs.			30 yrs.			50 yrs.		
						Sex	Height		Sex	Height		Sex	Height	
Sq. cm.	Cm.	Kg.	Lbs.	Gms.	Cu. Cm.		Cm.	In.		Cm.	In.		Cm.	In.
93	....	45	99	247	475	..	...	..	..	...	..	..	...	..
94	11.4	45.5	100	251	483	F.	140	55	..	...	..	..	...	....
95	11.5	46.5	102	255	490	F.	142	56	F.	130	51	..	...	....
96	....	47	104	259	498	M.	145	57	F.	135	53	..	...	....
97	11.6	48	105	263	506	F.	145	57	F.	137	54	..	...	....
98	11.7	48.5	107	267	514	M.	147	58	M.	137	54	F.	124	49
99	....	49.5	109	271	522	F.	150	59	F.	142	56	F.	132	52
100	11.8	50	110	275	530	M.	150	59	M.	152	56	M.	135	53
101	....	51	112	279	538	F.	152	60	M.	145	57	M.	137	54
102	11.9	51.5	114	283	546	M.	152	60	M.	147	58	F.	140	55
103	11	52.5	115	287	554	F.	155	61	F.	150	59	M.	142	56
104	12	53	117	292	562	M.	155	61	M.	150	59	M.	145	57
105	12.1	54	119	296	570	F.	157	62	F.	152	60	F.	145	57
106	12.2	54.5	120	300	578	M.	157	62	M.	152	60	M.	147	58
107	....	55.5	122	314	586	F.	160	63	F.	155	61	F.	147	58
108	12.3	56	124	309	595	M.	160	63	M.	155	61	M.	150	59
109	....	57	125	313	603	F.	163	64	F.	157	62	F.	150	59
110	12.4	58	127	317	612	M.	163	64	M.	157	62	M.	152	60
111	....	58.5	129	322	620	..	...	..	M.	160	63	M.	155	61
112	12.5	59	130	326	628	F.	168	66	F.	163	64	F.	155	61
113	....	60	132	330	637	M.	165	65	M.	163	64	M.	157	62
114	12.6	61	134	335	645	M.	168	66	F.	165	65	F.	157	62
115	....	61.5	136	339	653	F.	170	67	..	...	..	..	...	..
116	12.7	62.5	138	343	662	M.	170	67	M.	165	65	M.	160	63
117	12.8	63.5	140	348	671	..	...	..	..	...	..	F.	160	63
118	....	64	141	352	679	F.	173	69	M.	168	66	M.	163	64
119	12.9	65	143	357	688	M.	173	68	F.	170	67	F.	163	64
120	....	65.5	145	361	696	F.	178	70	F.	173	68	..	...	..
121	13	66.5	147	366	705	M.	175	69	M.	170	67	M.	165	65
122	....	67.5	149	371	714	F.	180	71	F.	175	69	..	...	..
123	13.1	68	150	375	723	M.	178	70	M.	173	68	M.	168	66
124	....	69	152	380	732	..	...	..	..	...	..	F.	168	66

125	13.2	70	154	384	741	F.	183	72	F.	178	70	F.	170	67
126	13.3	71	156	389	750	M.	180	71	M.	175	69	M.	170	67
127	....	71.5	158	394	759	..	...	..	F.	180	71	F.	171	67.5
128	13.4	72.5	160	398	768	M.	183	72	M.	178	70	M.	173	68
129	....	73.5	162	403	777	..	...	..	..	...	..	..	...	..
130	13.5	74	163	408	786	..	...	..	F.	185	72	F.	174	68.5
131	13.6	75	165	413	795	M.	185	73	M.	180	71	M.	175	69
132	13.6	76	167	417	804	..	...	..	..	...	..	..	...	..
133	....	76.5	169	422	813	M.	188	74	..	...	..	F.	178	70
134	13.7	77.5	171	427	823	..	...	..	M.	183	72	M.	178	70
135	....	78.5	173	431	832	..	...	..	..	...	..	..	...	..
136	13.8	79.5	175	436	841	M.	191	75	M.	185	73	F.	180	71
137	....	80	177	441	850	..	...	..	..	...	..	M.	180	71
138	13.9	81	179	446	860	M.	193	76	..	...	..	F.	183	72
139	....	82	181	451	869	..	...	..	M.	188	74	M.	183	72
140	14	83	183	456	878	..	...	..	..	...	..	..	...	..
141	....	83.5	185	460	887	..	...	..	..	...	..	..	...	..
142	14.1	84.5	187	465	897	..	...	..	M.	190	75	M.	185	73
143	....	85.5	189	470	906	..	...	..	M.	190	75	M.	185	73
144	14.2	86.5	191	475	916	..	...	..	..	...	..	..	...	..
145	....	87.5	193	480	925	..	...	..	M.	193	76	M.	188	74
146	....	88	195	485	934	..	...	..	..	...	..	..	...	..
147	14.3	89	197	490	944	..	...	..	..	...	..	..	...	..
148	....	90	199	495	954	..	...	..	..	...	..	..	...	..
149	14.4	91	201	500	964	..	...	..	..	...	..	M.	191	75
150	....	92	203	505	974	..	...	..	..	...	..	..	...	..
151	14.5	93	205	510	984	..	...	..	..	...	..	..	...	..
152	....	93.5	207	515	994	..	...	..	..	...	..	M	193	76
153	14.6	94.5	209	521	1004	..	...	..	..	...	..	..	...	..
154	....	95.5	211	526	1013	..	...	..	..	...	..	..	...	..
155	14.7	96.5	213	531	1023	..	...	..	..	...	..	..	...	..
156	....	97.5	215	536	1033	..	...	..	..	...	..	..	...	..
157	14.8	98.5	217	541	1043	..	...	..	..	...	..	..	...	..
158	....	99.5	219	546	1053	..	...	..	..	...	..	..	...	..
159	14.9	100	221	551	1063	..	...	..	..	...	..	..	...	..
160	....	101	223	557	1073	..	...	..	..	...	..	..	...	..
161	15	102	225	562	1083	..	...	..	..	...	..	..	...	..
162	....	103	227	567	1093	..	...	..	..	...	..	..	...	..
163	....	104	230	572	1104	..	...	..	..	...	..	..	...	..
164	15.1	105	232	578	1114	..	...	..	..	...	..	..	...	..
165	....	106	234	583	1124	..	...	..	..	...	..	..	...	..
166	15.2	107	236	588	1134	..	...	..	..	...	..	..	...	..
167	....	108	238	593	1144	..	...	..	..	...	..	..	...	..
168	....	109	240	599	1154	..	...	..	..	...	..	..	...	..
169	15.3	110	242	604	1164	..	...	..	..	...	..	..	...	..
170	....	111	244	610	1175	..	...	..	..	...	..	..	...	..

TABLE (Bardeen)—*Continued*

Heart Silhouette Area	Approx. Trans. Diam.	Weight of Body		Weight Heart Empty	Volume Heart Diastole	Height at given age for given weight								
						20 yrs.			30 yrs.			50 yrs.		
						Sex	Height		Sex	Height		Sex	Height	
Sq. cm.	Cm.	Kg.	Lbs.	Gms.	Cu. Cm.		Cm.	In.		Cm.	In.		Cm.	In.
171	....	112	246	615	1185	..	...	..	..	...	..	..	...	..
172	15.4	113	248	620	1195	..	...	..	..	...	..	..	...	..
173	....	114	250	626	1206	..	...	..	..	...	..	..	...	..
174	15.5	115	253	631	1216	..	...	..	..	...	..	..	...	..
175	....	116	255	637	1227	..	...	..	..	...	..	..	...	..
176	15.6	117	257	642	1233	..	...	..	..	...	..	..	...	..
177	....	118	260	648	1249	..	...	..	..	...	..	..	...	..
178	15.7	119	262	653	1259	..	...	..	..	...	..	..	...	..
179	....	120	264	658	1269	..	...	..	..	...	..	..	...	..
180	15.8	121	266	664	1280	..	...	..	..	...	..	..	...	..
181	....	122	268	669	1290	..	...	..	..	...	..	..	...	..
182	15.9	123	271	675	1301	..	...	..	..	...	..	..	...	..
183	....	124	273	681	1312	..	...	..	..	...	..	..	...	..
184	16	125	275	686	1322	..	...	..	..	...	..	..	...	..
185	....	126	277	692	1333	..	...	..	..	...	..	..	...	..
186	16.1	127	279	697	1344	..	...	..	..	...	..	..	...	..
187	....	128	282	703	1355	..	...	..	..	...	..	..	...	..
188	16.2	129	284	708	1366	..	...	..	..	...	..	..	...	..
189	....	130	286	714	1377	..	...	..	..	...	..	..	...	..
190	16.3	131	288	720	1388	..	...	..	..	...	..	..	...	..
191	....	132	290	726	1399	..	...	..	..	...	..	..	...	..
192	....	133	293	732	1410	..	...	..	..	...	..	..	...	..
193	16.4	134	295	737	1421	..	...	..	..	...	..	..	...	..
194	....	135	297	743	1432	..	...	..	..	...	..	..	...	..
195	....	136	299	748	1443	..	...	..	..	...	..	..	...	..
196	16.5	137	301	754	1454	..	...	..	..	...	..	..	...	..
197	....	138	304	759	1465	..	...	..	..	...	..	..	...	..
198	....	139	306	765	1476	..	...	..	..	...	..	..	...	..
199	16.6	140	308	770	1487	..	...	..	..	...	..	..	...	.
200	....	141	310	776	1499	..	...	..	..	...	..	..	...	.

spine of the ninth thoracic vertebra; patient to hold breath after a moderately deep inspiration. A good intensifying screen should be used. It is advisable to give the patient a glass of water to drink immediately before making the exposure and have him swallow air with the water. The resulting air bubble in the stomach aids in outlining the apex of the heart.

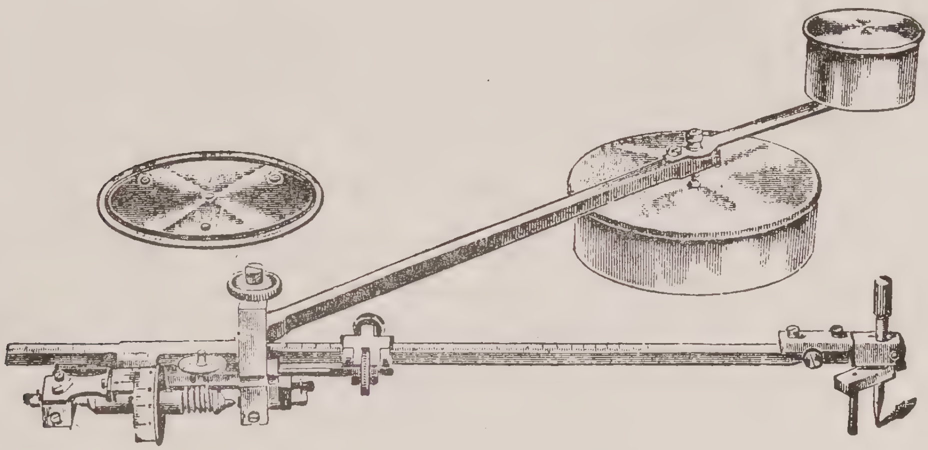


FIG. 190. Planimeter.

After the radiograph is dry it is best to accentuate the outline on the plate by india ink or a soft black pencil, and the unregistered outline must be filled in as shown in Fig. 188. Then a tracing is made on paper (Fig. 189) and the area is determined either by a planimeter[1] (Fig. 190), or by ruling parallel lines one centimeter apart in two directions at right angles and counting squares, estimating fractions. The lines MR, ML, Figs. 188 and 189, and the diameter of the aortic arch and a point indicating the median line of the body should be indicated on the tracing. The record furnished should include: (a) weight of patient stripped, (b) age, (c) height without shoes, (d) trans-

[1] Instructions for the use of a planimeter are furnished with the instrument by the maker and these instructions should be carefully observed. The user will find it advisable to check his work by laying out a rectangular diagram of known area and testing the accuracy of his reading by measuring the same.

verse diameter MR + ML, (e) aortic diameter, (f) heart area from tracing.

In using this method it is assumed that the increase in area of heart shadow on the plate due to the fact that the rays are not parallel is equivalent to the usual increase in shadow area for the sitting position over that for the standing position.

From the tables read: the normal heart area shadow, diameter and volume (1) for a person of the same height, (2) for one of the same weight as the patient. The area (f) should fall between the normal for like height and that for like weight. If the area (f) is less than the smaller, or exceeds the greater of those taken from the table the heart may be regarded as of abnormal size.

In such cases compute the per cent variation of (f) from the nearer of the two from the table and enter on the record. If this exceeds 10 per cent and symptoms are present, there is a fair probability of pathology.

URINARY TRACT

It is not necessary at the present day to discuss the obvious value and importance of the x-ray examination of the urinary tract. It is sufficient to state that it is the best and only single method of demonstrating the presence of a calculus; that furthermore it also discloses its location, its size, and its shape, and tells the number, if more than one are present. For this reason it is a very valuable aid in the decision whether operative procedure is necessary or an expectant course is permissible. In the latter eventuality it is the only means at our disposal which tells us whether the calculus is passing downward or remains stationary, whether it increases in size, and whether there is a tendency for the formation of additional calculi.

Preparation of the Patient.—To obtain satisfactory results it is necessary to eliminate confusing shadows of substances found in the gastro-intestinal tract and to get rid of accumulations of gas in the colon which tend to obscure the kidney shadows and may obliterate small calculi. For that reason it is a condition precedent to every examination of the urinary tract to prepare the patient by thorough catharsis. Castor oil, about 1½-2 ounces for an adult, is the best cathartic for this purpose, as it helps to eliminate gas. If, for a good and sufficient reason, it cannot be used, a large dose of one of the other vegetable cathartics may be given. The metallic substances, in particular calomel, should never be used, because they have a tendency to produce gas.

The cathartic should be administered the evening before the examination, the patient abstaining from all food in the interval. For that reason it is best to make these examinations in the morning, omitting breakfast, but allowing the patient to take a little coffee or tea. If the examination is made later in the day the patient might have to starve too long.

An enema, if properly administered, would be of assistance. Experience, however, teaches that it is very difficult to have it done properly, and for that reason it should be avoided as a routine measure. In those cases, however, where the administration of catharsis is contraindicated or time does not permit it, *a low S. S.* enema may be given an hour before the examination, the tube being retained in the rectum for half an hour to facilitate the escape of gas.

If it can be avoided, the patient should not be examined during or immediately following an attack of colic. During an attack he is usually too sick for such an examination. Besides, at that time and immediately after, he is invariably under the influence of an opiate or similar drug which interferes with efficient catharsis and almost always causes the accumulation of gas in the colon.

Technique.—Several observers, notably Shenton and Manges, have advocated fluoroscopy in the examination of the urinary tract. While in the hands of careful and exceptionally skillful operators this method is of value, yet in the hands of the average operator radiography yields the best results. Therefore this article is based entirely upon the radiographic method.

The most common method employed in the examination of the urinary tract is the one in which the patient is in the recumbent position, the tube placed above, the plate below. Most roentgenologists use, in addition to the plain

diaphragm, the compression cylinder or cone. Some operators, however, use merely the diaphragm, and others, notably Caldwell, place the patient in the prone position, the tube below the table and the plate above the patient at the back, Fig. 191. Placing a rubber bag filled with air under the patient, his weight will produce the necessary compression in this position. Inasmuch as the base hospital tables

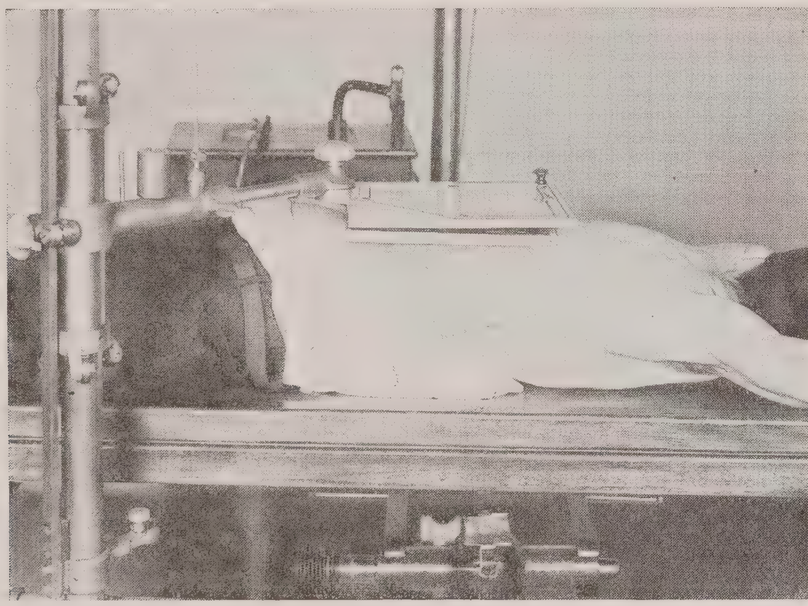


FIG. 191. Patient prone; tube below table; plate held against patient's back by screen holder. This illustration shows examination for upper half. Tube and plate would have to be moved downward to bladder region for lower half.

used in the army are arranged for work with the tube above, the technique best adapted for these tables will be described here. There are many variations in the technique employed. When a small cylinder or cone is used it is necessary to make five exposures to cover the urinary tract, namely, one for each kidney, and the upper third of each ureter, one for the middle portion of each ureter, and the fifth for the lower third of both ureters and for the bladder. Others, by using a slightly larger cylinder, make only

four exposures, including the middle third of both ureters, on one plate. The writer prefers to use a cylinder, 8½ inches in diameter, which enables him in the majority of cases to make one exposure (or set of stereoscopic exposures) for the upper half, Fig. 192, and another for the lower half, Fig. 193, of the urinary tract. This technique is sometimes modified to suit individual cases. If the patient is

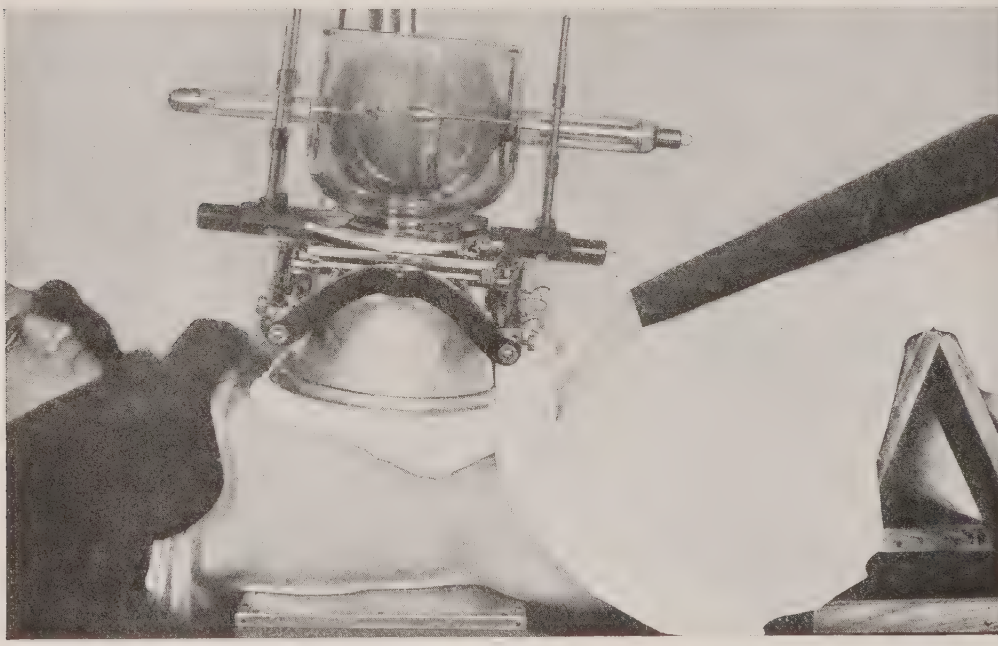


FIG. 192. Position for upper half of urinary tract; showing compression sponge, knee support and insulating sheet protecting patient's knees against spark from terminal of tube.

very stout, it is necessary to make special exposures over individual kidney regions. Similarly, special exposures are made over regions which are particularly under suspicion or for which a confirmatory examination is desired.

In older men and in all cases where concretions in the prostate are suspected, an examination of the bladder region should be made in the dorsoventral position. In this exposure the tube should be tilted slightly upwards and cen-

tered as nearly as possible on the sacrococcygeal junction, Fig. 194.

In all cases the entire urinary tract should be examined no matter whether the symptoms point to a definite region or not. Only by observing this rule will mistakes in diag-

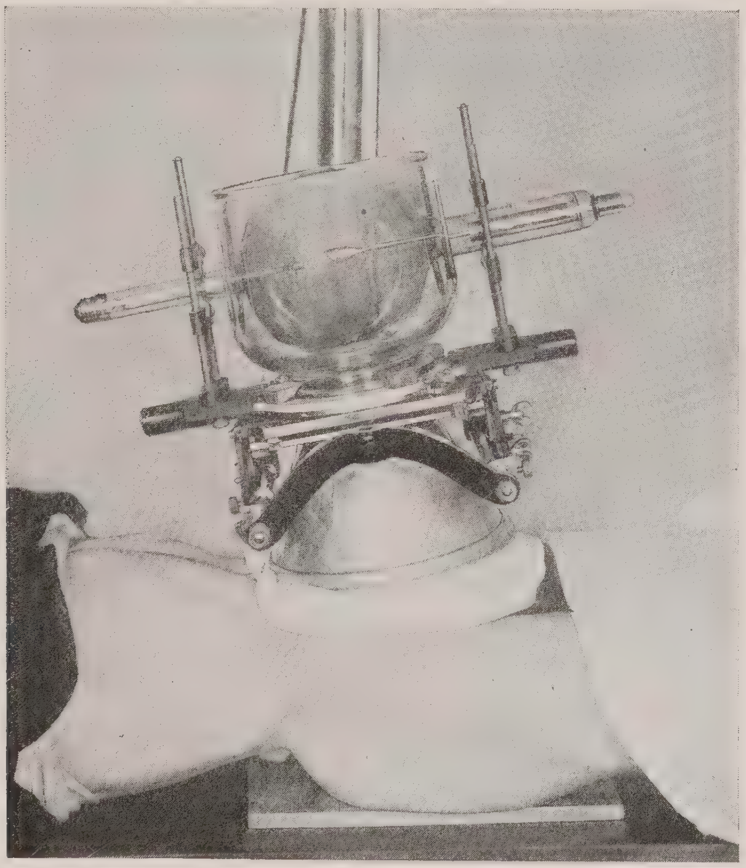


FIG. 193. Position for lower half of urinary tract.

nosis be avoided. For, in a great number of instances the calculus may be found on the side opposite to that indicated by the symptoms. An examination of a single area is permissible only when it is done for verification.

In making the examination with the cylinder, it is advisable to tilt it upwards for the upper half and downwards for the lower half. The operators who are examin-

ing individual areas with the smaller cylinders or cone as a rule try to get the upper rim of the cylinder under the free border of the ribs. (The term upper and lower are made with reference to the patient, the upper referring to cephalic, the lower to caudal end.) The advantage obtained by

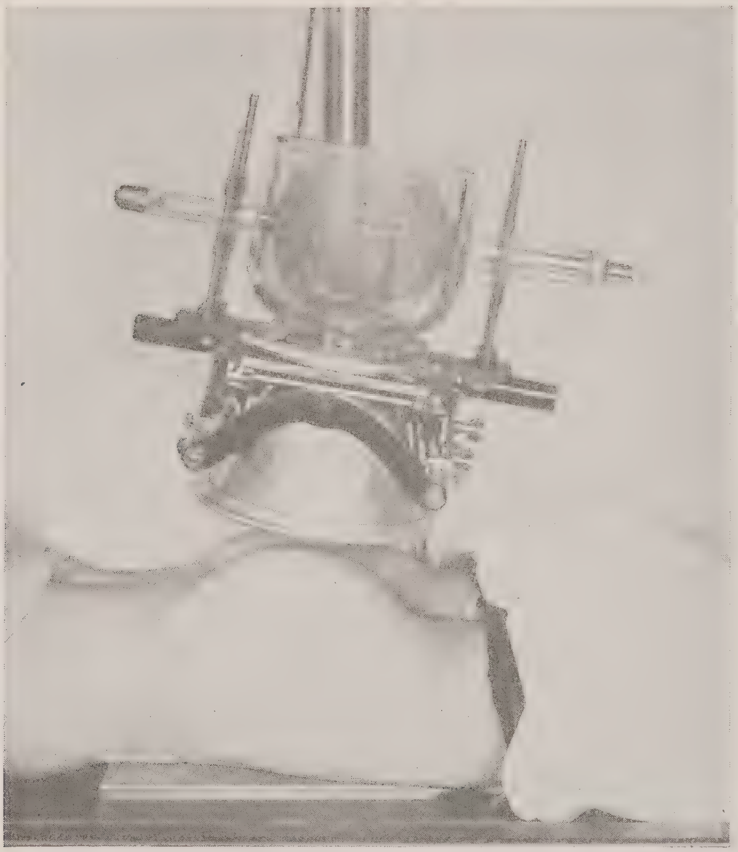


FIG. 194. Position for bladder and prostate.

getting the cylinder or cone under the ribs is that calcifications in the costal cartilages are not projected upon the kidney shadows, and thus confusion is avoided.

The beginner will soon learn which are the best angles for the apparatus he is using. As a guide he should use the accompanying illustrations until he has acquired his technique.

Various devices are employed in order to prevent the abdominal wall from protruding into the opening of the cone. One of these is the attachment of an aluminum hemisphere to the lower opening of the cone. Another is to place between the cylinder or cone and the patient's abdomen a rubber bag filled with air or a pad made of loofah sponges, or absorbent cotton. These must be wider than the rim of the cylinder or cone and of ample thickness. They should be tested by radiography or fluoroscopy to ascertain that they are free from shadow-casting substances.

Quality of Tube.—It is best to use a tube of fairly low gap, about 3 to 4 inches (using a slightly lower gap perhaps for the Coolidge than for the gas tube) at 40 ma. or more. The length of exposure depends upon the speed of the plate and the current used. It may vary from 2 to 6 and be as long as 10 and 15 seconds. Great rapidity is not needed, if the parts can be properly immobilized and the patient can be made to hold his breath during the exposures over the upper half of the urinary tract. Complete arrest of respiration holds the diaphragm still and the kidneys at rest, enabling the operator to obtain good kidney outlines.

Position.—It is very important to have the spine straightened out, so that it completely touches the plate. In those instances (and they are many) where the patient's back is so curved that the simple recumbent position will not straighten it sufficiently, his shoulders may have to be raised and the hips and knees flexed. When doing the latter, one must be careful not to bring the tube terminals too near the knees. If that cannot be prevented, a good heavy insulator ought to be interposed, and if that is not feasible, one had better allow the back to remain curved (Fig. 195).

Clothing or bandages in the path of the rays between the target and the plate should be avoided. In case the removal

of bandages is not permissible correct information as to what is hidden by them must be obtained before stating definitely that a certain shadow is a calculus. It is well to remember that dried blood or pus in a bandage or dressing will cast a shadow.

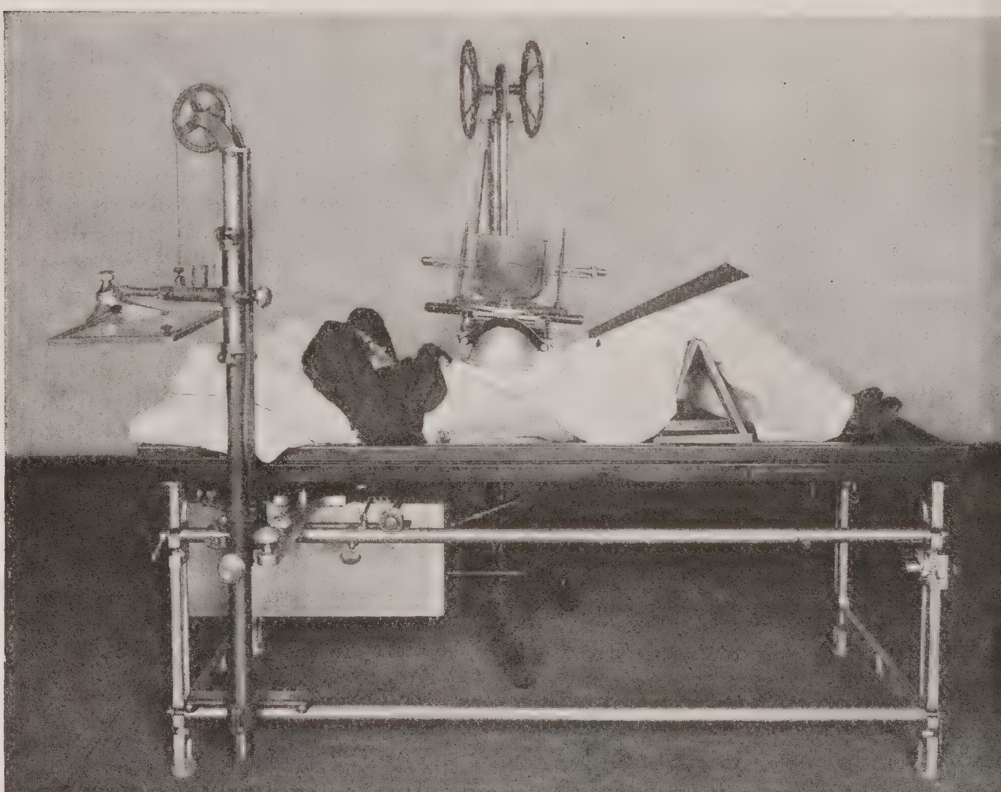


FIG. 195. General view of table; position of patient on table and method used in straightening patient's back; relative position of table and tube stand on side opposite to screen carrier.

Quality of the Plate.—The greatest difficulty in this examination is encountered when no calculus is seen on the plate. The question then arises, is the plate good enough to make a negative diagnosis with absolute certainty. Credit is due to the late Charles Lester Leonard, of Philadelphia, for having laid down the rules which with but one addition hold good to-day. These rules are: a plate to be consid-

ered as having the necessary radiographic quality must show at least the 11th and 12th ribs, the transverse processes of the lumbar vertebræ, and the edge of the psoas muscle. The only addition to Leonard's rule is that at the present day one must also demonstrate the kidneys. In the days of Leonard the x-ray technique had not been developed sufficiently to enable us to obtain kidney shadows in all cases. Even to-day it is sometimes difficult to live up to this rule. The right kidney is frequently obscured by the presence of gas at the hepatic flexure. But when on a plate showing both sides of the upper half of the urinary tract, one kidney is clearly shown, we may accept the plate as of good quality, though it does not show both kidneys clearly. Another point to remember is that great contrast between the spine and pelvis on the one hand, and the soft tissues on the other, is not desirable. Such a plate presupposes an overexposure with a tube of low penetration in which a small calculus may have been obliterated.

Pyelography.—In the vast majority of cases, the simple x-ray examination of the urinary tract is made for the determination of the presence or absence of a calculus. Other conditions of the tract cannot be determined readily or at all by such an examination. It is then necessary to resort to additional methods in such cases.

The most important of these methods is pyelography, i. e., the demonstration of the renal pelvis and calyces, of the ureter, and of the bladder, by the injection of substances which are opaque to the rays. The substance most commonly used in this country at the present day is a solution of thorium nitrate in about 10-15 per cent strength. Collargol, argyrol, and other silver compounds which ere originally used are now less generally employed. Other substances, especially insoluble ones, such as bismuth emulsions, should never be used. As they cannot be com-

pletely washed out they may form a good nucleus for the formation of a calculus. Thorium nitrate is the least harmful of all these substances. The method of injection is either by gravity, allowing the solution to flow in slowly, or by hand injection. The advocates of the gravity method maintain that only by using it are the deleterious effects of pyelography avoided. It is the writer's opinion, based upon considerable experience, that the method makes little difference. In the hands of a careful urologist, either method is good. But no matter how careful a urologist, neither method is free from danger. Pyelography, therefore, should be employed only when all other means have failed. The roentgenologist should never attempt the injection himself.[1]

The principal conditions which may be demonstrated by pyelography are the following:

1. Enlargement of the renal pelvis, congenital or acquired, such as hydronephrosis and pyonephrosis.
2. Malformations of the renal pelvis, most commonly due to tumor of the kidney.
3. Cystic kidney.
4. Horseshoe kidney.
5. Fused kidney.
6. Identification of shadows within the kidney outline as extrarenal or intrarenal.
7. Constriction or kink in the ureter.
8. Diverticulum in the ureter.
9. Hydro-ureter.
10. Redundant ureter.
11. Double ureter and pelvis.
12. Size and shape of bladder.

Demonstration of Calculi.—Calculi are demonstrable to

[1] Those interested in this subject are referred to Braasch's excellent monograph on pyleography, published by Saunders in 1915.

a greater or lesser extent according to their chemical composition. The oxalates and the calcium carbonates give the best shadows; the phosphates are next in density; the urates may be shown very faintly but generally not at all. Fortunately, the latter are infrequent in the ureter and quite rare in the kidney. In the bladder, where they occur most often, cystoscopy comes to our aid in locating them.

By far the greatest number of calculi are found in the ureters. The smallest number are found in the bladder. Renal calculi are second in frequency. They are often seen to be of very large size, sometimes occupying about two-thirds or more of the kidney and all of its pelvis. They are very often bilateral, and frequently multiple in one kidney. Occasionally such a calculus represents a complete cast of the renal pelvis and of all the calyces. A small calculus may be readily overlooked, especially when its shadow coincides with that of the rib or is situated just at the tip of the rib. The small calculi are frequently shown faintly because of the comparative density of the kidney shadow. For that reason it is difficult to distinguish them from the rib if they happen to be projected upon it. Stereoscopic examination will usually help in separating the shadows of the calculus and of the rib. Where stereoscopy is not feasible, a change in the angle of projection may sometimes throw these two shadows apart.

Whenever a faint shadow is seen which is suggestive of a calculus, especially if it is located in the kidney regions, a confirmatory examination should be made before making the diagnosis absolute. It is good policy in almost all cases to make a confirmatory examination before operation.

The demonstration of vesical calculi is generally much more difficult and less satisfactory than that of other calculi. The reason is, first, that the great majority of them are composed of pure uric acid or of a combination of

urates; secondly, they occur largely in individuals with prostatic disease, with thickened bladder walls, and marked retention of urine, all of which add to the difficulty in demonstrating them by the x-ray.

Prostatic concretions are readily demonstrable, but are not very frequent.

To demonstrate uric acid calculi in the ureter, pyelography, or more strictly speaking, ureterography, may have to be employed. The opaque solution will cover the transparent calculus for the time being, cr will ascend to that area and show a dilatation of the ureter at that point, thus demonstrating the calculus. Fortunately, the percentage of such calculi is small.

Sources of Error in Diagnosis.—Not every concretion or shadow seen on x-ray plates of the urinary tract is a urinary calculus. While it requires a great deal of experience to differentiate between them readily, it is still possible to give the beginner a fair idea how to avoid errors in diagnosis.

In the kidney regions, for example, small shadows, sometimes rather indefinite, are freqeuntly seen. Careful scrutiny of the plate may indicate that the direction of the calcification is in line with the costal cartilages. The difficulty here is not so pronounced when these concretions are in the cartilages of the free border. It is greater when there is a short 12th rib, the tip of which is seen within the kidney outline, and whose cartilage shows partial calcification, so that the latter appears to be separate and distinct from the rib itself. Occasionally intestinal contents at the hepatic or splenic flexures may cause considerable difficulty in the interpretation. Calcified mesenteric glands are another source of difficulty. In the lower part of the urinary tract, especially near the bladder, there are

seen, with very great frequency, a number of small concretions whose shadows are very dense and circular in outline and quite distinct in contour, which are not calculi. For want of a better name they have been called phleboliths.

The following is a partial list of shadow-producing substances reported by various authors which have given rise to confusion in diagnosis. It necessarily cannot be complete.

1. Fruit pits.

2. Fecaliths; the most confusing of these is a concretion in the appendix, because of its shape and position and also because it frequently gives rise to symptoms resembling those of urinary calculus. Microscopic blood has even been found in such cases.

3. Residues of metallic medication such as bismuth, barium, Blaud's pills, etc.

4. Foreign bodies in the intestinal tract, including Murphy's buttons. The latter, however, can be more readily recognized by their characteristic shape and also from the history.

5. Gall-stones; a differential point for these is that they are usually about the size of a cherry pit, distinctly outlined, either sharply circular or facetted, and are more transparent in the center than at their margin.

6. Calcified mesenteric glands; these can be recognized to some extent by their appearance. They are usually not as compact and dense as urinary calculi but are reticulated. They are as a rule quite mobile, so that they will change their position with regard to the kidney to a greater extent than can be accounted for by even the grossest distortion in position.

7. Calcifications in tuberculous kidneys and inspissated

pus. These, though strictly speaking, not calculi, may for practical purposes be considered such.

8. Calcified blood clot in a carcinomatous kidney. Abscess of kidney with scar tissue in the kidney.

9. Carcinoma in the head of the pancreas.

10. Calcifications at the bifurcation of the aorta.

11. Calcification of the tips of the transverse processes of the lumbar vertebræ, or artefacts in this region produced by the crossing of the border of the psoas muscle just inside the tip.

12. Calcifications in the body portions of the pelvis, especially in the ilium, the so-called compact islands, and small exostoses of the ilium or of the ischial spine.

13. Calcifications of portions of the ureter.

14. Sclerosis of the iliac arteries.

15. Calcifications of the vasa deferentia.

16. Calcified myoma or dermoid cyst.

A thorough inspection of the body surface of the patient at the time of the examination will aid in avoiding confusion in the following instances:

17. Warts and pigmented moles, especially when in good approximation to the plates.

18. Scars of former operations.

19. Adhesive plaster, especially when tied in a knot or folded.

Shadows due to intestinal contents are usually absent at a reëxamination after more thorough catharsis. If shadows persist after repeated catharsis and their nature is still doubtful, it will be necessary to reëxamine the patient with an opaque catheter in the suspected ureter, preferably stereoscopically, before one can tell whether this

shadow is due to a concretion in the urinary tract or outside of it.

In one instance mentioned above, namely, calcifications of portions of the ureter, even the opaque catheter may not help to clear up the condition, because it will usually be arrested at the area of calcification and in this way apparently confirm the presence of a calculus. For practical purposes this makes no difference, inasmuch as surgical removal of the calcified portion of the ureter is necessary to relieve the patient of his symptoms.

Use of the Opaque Catheter.—In all doubtful cases where shadows are seen within or near the course of the ureter, the diagnosis can be rendered more certain by a reëxamination with an opaque catheter in the suspected ureter. Though the ureter follows a fairly regular course, there frequently are deviations from the normal, which seem to place a shadow outside of the ureter. The opaque catheter, especially when aided by the stereoscope will assist in making the diagnosis.

GASTRO-INTESTINAL TRACT

In the x-ray examination of the gastro-intestinal tract we must remember that we are not dealing with fixed organs, but with those that vary greatly in size, shape, position and motility according to conditions. It is therefore difficult to differentiate between supposedly abnormal indications, either congenital or temporary, and those that are pathological. The most definite of the latter are as follows:

1. Interference with function.
2. Irregularities in outline, such as,
   - Filling defects,
   - Projections,
   - Niches,
   - Diverticula,
   - Hourglass deformities,
   - Spasms.
3. Extreme changes in position.

Technique.—Since the gastro-intestinal tract is not directly demonstrable by the x-ray, it is necessary to introduce some opaque substance which should not interfere with function and must be harmless.

"Barium Sulphate for X-Ray Diagnosis" is the agent most commonly employed. While the constituents of the barium meal vary with many operators, it is well to emphasize that, whatever meal is used, it should be adhered to in all examinations, as different meals may cause marked differences in function, especially of the stomach.

In studying the lesions of the esophagus, a thick paste made of barium sulphate and mucilage of acacia should be employed. A barium water mixture should be used first, as a very narrow stricture may be present. For the study of the stomach, 4 oz. of barium sulphate mixed with 12 oz. of buttermilk, or one of the fermented milks, is the favorite among American roentgenologists. If these cannot be obtained, an emulsion of mucilage of acacia and barium sulphate with water can be readily substituted.

The opaque enema is composed of 8 oz. of barium sulphate and 32 oz. of water with sufficient mucilage of acacia to make an emulsion. Other vehicles, such as buttermilk or a mixture of equal parts of condensed milk and water, may be used. Barium or bismuth or any other of these opaque substances when mixed with water alone sediments out too quickly and should therefore not be used except as above noted.

Preparation of the Patient.—For the examination of the esophagus and the stomach by an ingested meal, the patient should present himself with an empty stomach but *without* previous catharsis. When the opaque enema is to be used the colon is prepared by the administration of several cleansing enemata, the last of these at least two hours before examination. All drugs which have a stimulating or inhibitory effect upon the digestive tract should be withdrawn at least twenty-four hours before the examination. With the barium meal as described above the stomach empties normally in about four hours. But if the barium is retained up to six hours it is still considered within normal limits. A retention after six hours of about one-eighth or more of the ingested quantity is distinctly pathological. On the other hand, perfectly normal stomachs have been seen to empty in about two hours. In these cases, however, one should remember that achylia gastrica

is characterized by very rapid emptying time. The small intestines should be empty six hours *after the stomach is clear.* The cecum begins to fill about four hours after the

FIG. 196. Diverticulum arising from posterior wall of esophagus.

meal; the head of the barium column is at the hepatic flexure at six hours after the meal, in the midportion of the transverse colon at eight hours and in the lower portion of the descending colon at twelve hours. Part should be dis-

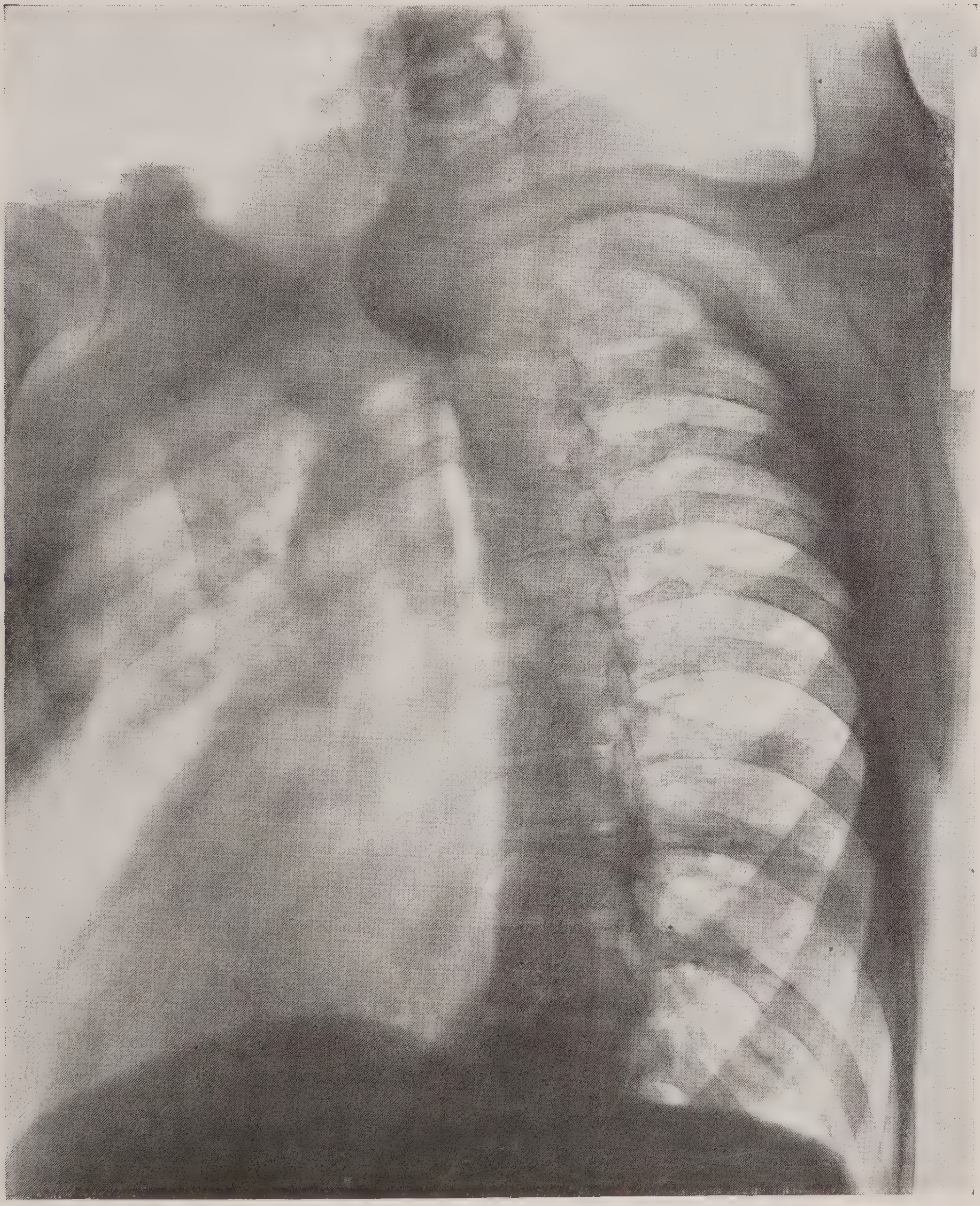


FIG. 197. Benign stricture of esophagus.

charged about twenty-four hours after the meal and a complete evacuation ought to be accomplished in forty-eight hours.

Method of Examination.—In making an examination, a combination of the fluoroscopic and radiographic meth-

ods should be employed. Both methods give information as to size, position, shape and contour. Plates give full detail, especially in contour, and form a permanent record. The screen has the great advantage of permitting the observer to study the tract in motion and to palpate individual organs. It is therefore indispensable.

The Esophagus.—This should be examined for the following lesions: Diverticula, benign strictures, malignant growths and spasms.

Diverticulum is usually found just below the jugular notch. Since it may lie anteriorly, posteriorly or laterally it should be viewed from various angles. It manifests itself by a shadow outside that of the esophagus and is generally pouchlike in appearance and persists after the esophagus is empty, Fig. 196.

Benign strictures and malignant growths are similar in appearance; in both there is a constriction at the seat of the lesion which is usually conical in shape, the apex pointing downward, accompanied by a varying degree of obstruction. An etiological diagnosis between these two conditions cannot always be made but when the edges of the stricture are serrated it is more likely to be malignant, Fig. 197 and Fig. 198. In malignancy little dilatation, if any, is observed, and it is usually found at the level of the bifurcation of the trachea and in the cardiac end. When the latter obtains, the adjacent part of the stomach is frequently involved. Benign strictures may be found in any portion of the esophagus. Age will frequently aid in the determination of the condition.

Spasm is intermittent in character, may occur in any part and is usually transitory. The most common form is *cardiospasm.* It is more or less persistent and results in a dilatation of the entire esophagus to a degree not seen in any other conditions, Fig. 199.

FIG. 198. Carcinoma of esophagus at level of bifurcation of trachea.

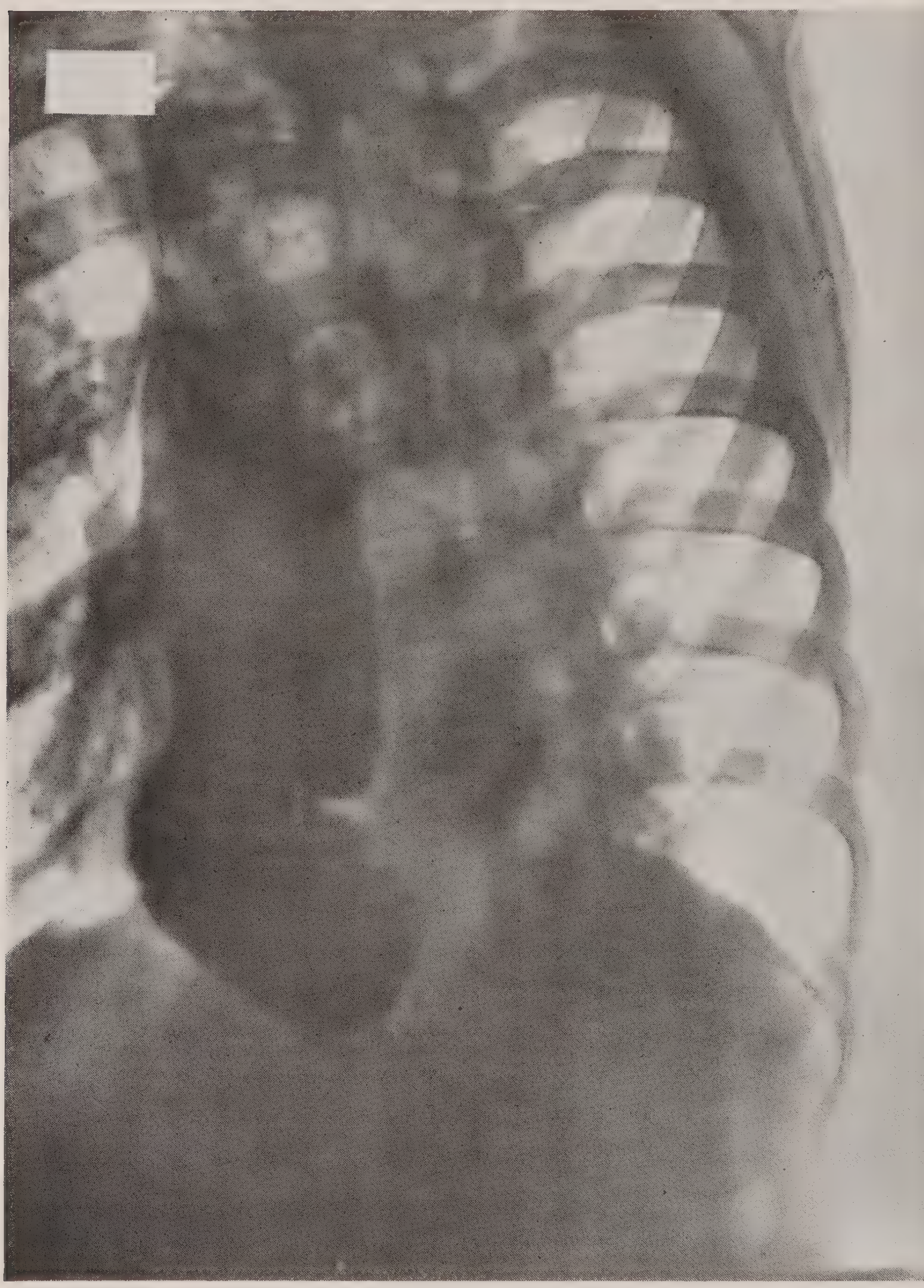


FIG. 199. Cardiospasm; note marked dilatation of esophagus.

Stomach.—The size, position and shape of the stomach depend upon the habitus of the individual.

Fig. 200. Penetrating ulcer on lesser curvature of stomach. Spastic hourglass contraction opposite on greater curvature.

Roughly speaking, the high transverse stomach is found in fat people, the cow-horn type in the medium weight individuals, the fish-hook type more frequently in thin indi-

viduals, but variations from these accepted positions are common. These positions are well worth remembering as

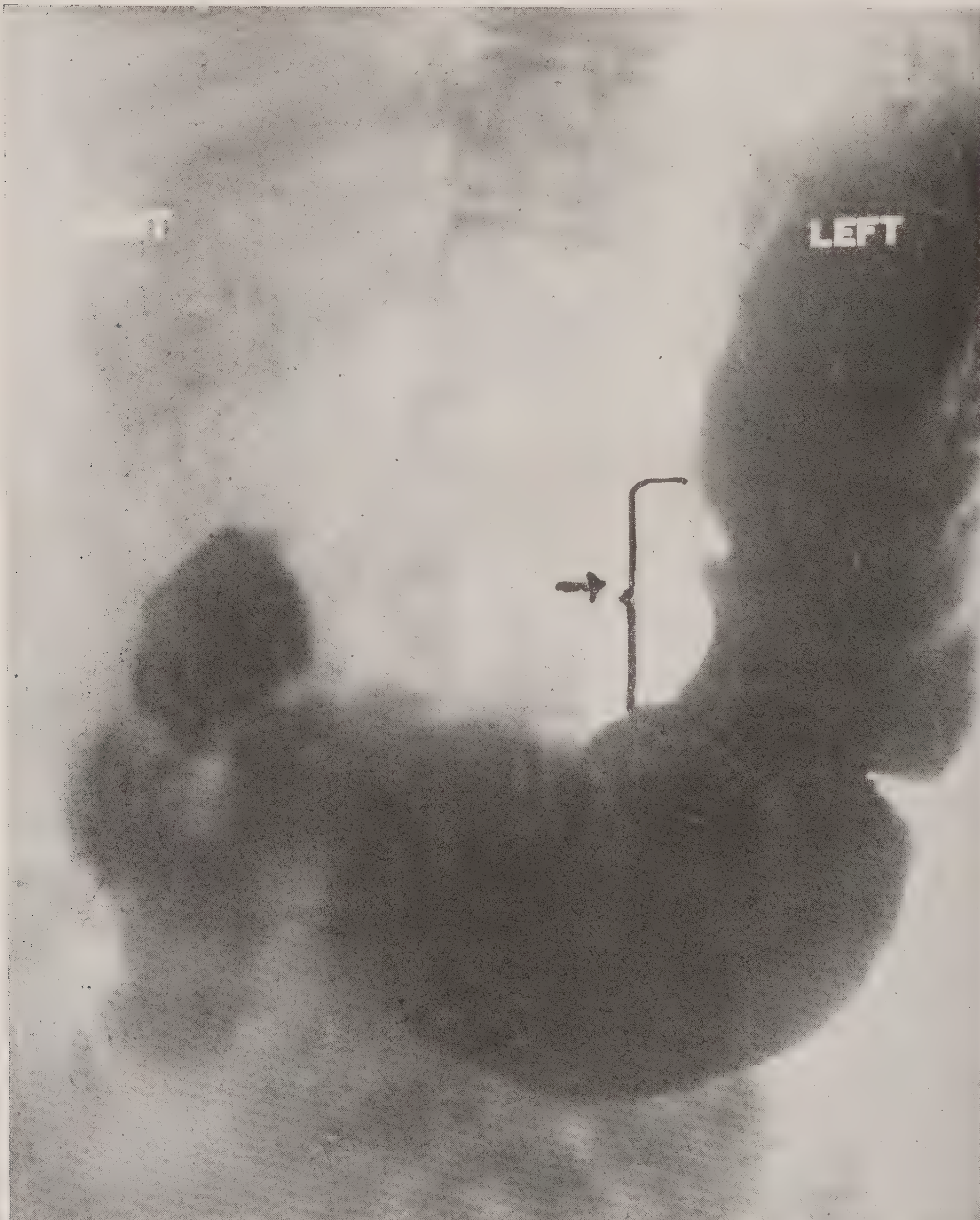


FIG. 201. Excavating ulcer of lesser curvature, indicated by bracket.

they play an important part in motility. As a general rule the high normal stomach empties more quickly than the

normal fish-hook type. Function is more important than position.

The two lesions that concern us chiefly are ulcer and malignancy; of the latter carcinoma is by far the most frequent. The signs of ulcer of the stomach are as follows:

1. The *niche and accessory pocket* are seen in penetrating ulcer. They appear as projections from the gastric silhouette and vary in size and shape, Fig. 200. The vast majority of ulcers are situated on the lesser curvature within two inches of the pylorus. Large nonpenetrating ulcers can be readily recognized by a smooth, shallow filling defect, Fig. 201. Small nonpenetrating acute ulcers may not be seen directly, but can often be recognized by a jumping of the peristaltic wave and by tenderness at that area.

2. *Hourglass.*—The organic *hourglass* is the result of cicatrization and is permanent.

3. *Spasm.*—There are two varieties: general and local. The local simulates organic hourglass in contour and location, but is evanescent in character. General spasm affects the entire stomach so that there is an absence of peristaltic waves. Both can be overcome by paralyzing the musculature by physiological doses of atropine, and this is the only method by which the spasmodic hourglass is differentiated from the organic. It is well to remember that spasmodic hourglass often occurs on the greater curvature opposite a gastric ulcer, Fig. 200.

4. *Modified Peristalsis.*—There is usually hyperperistalsis, especially in the early part of the examination, associated with spasm of the pylorus and consequent delay in expulsion.

While the above signs are indicative of ulcer, yet it is seldom that all of them are seen in the same case. When,

FIG. 202. Marked dilatation of stomach due to obstruction at pylorus (prone position).

for instance, the ulcer is situated at the pylorus, causing obstruction that has persisted for some time, spasticity and hyperperistalsis are lost, being replaced by the dilated atonic stomach, Fig. 202.

Carcinoma may be situated in any portion of the stomach, but the most frequent location is at the pyloric end. Unlike ulcer at the pylorus it may be quite extensive without producing obstruction.

The chief signs of malignancy are:

1. *The Filling Defect.*—An irregular serrated defect due to the projection of the growth into the lumen of the stomach, Figs. 203 and 204.

2. *Modified Peristalsis.*—The infiltration of the gastric wall causes a diminution, or even absence, of peristalsis in the involved area.

3. *Emptying Time.*—When obstruction is present, the time varies according to the degree of occlusion. On the other hand, it may happen that the pyloric ring is so infiltrated that it does not obstruct, but, on the contrary, cannot contract, and then there is rapid clearance.

When growths occur on the greater curvature, the lesions manifest themselves by filling defects of varying size. In this condition the function of the stomach is so little disturbed that an early clinical diagnosis is often impossible. On this account this region is spoken of as the silent area. All lesions on the greater curvature should be viewed with suspicion as to malignancy, as ulcers occur almost entirely on the lesser curvature. In carcinoma of the cardiac end, the accompanying esophageal stenosis calls the patient's attention to the condition and renders an early clinical diagnosis possible. Radiologically this condition is recognized by a varying degree of obstruction at the cardia.

Small Intestine.—The most common lesion in the

duodenum is ulcer. The chief points of diagnosis are as follows:

1. Deformity of the Duodenal Bulb (Cap).—This re-

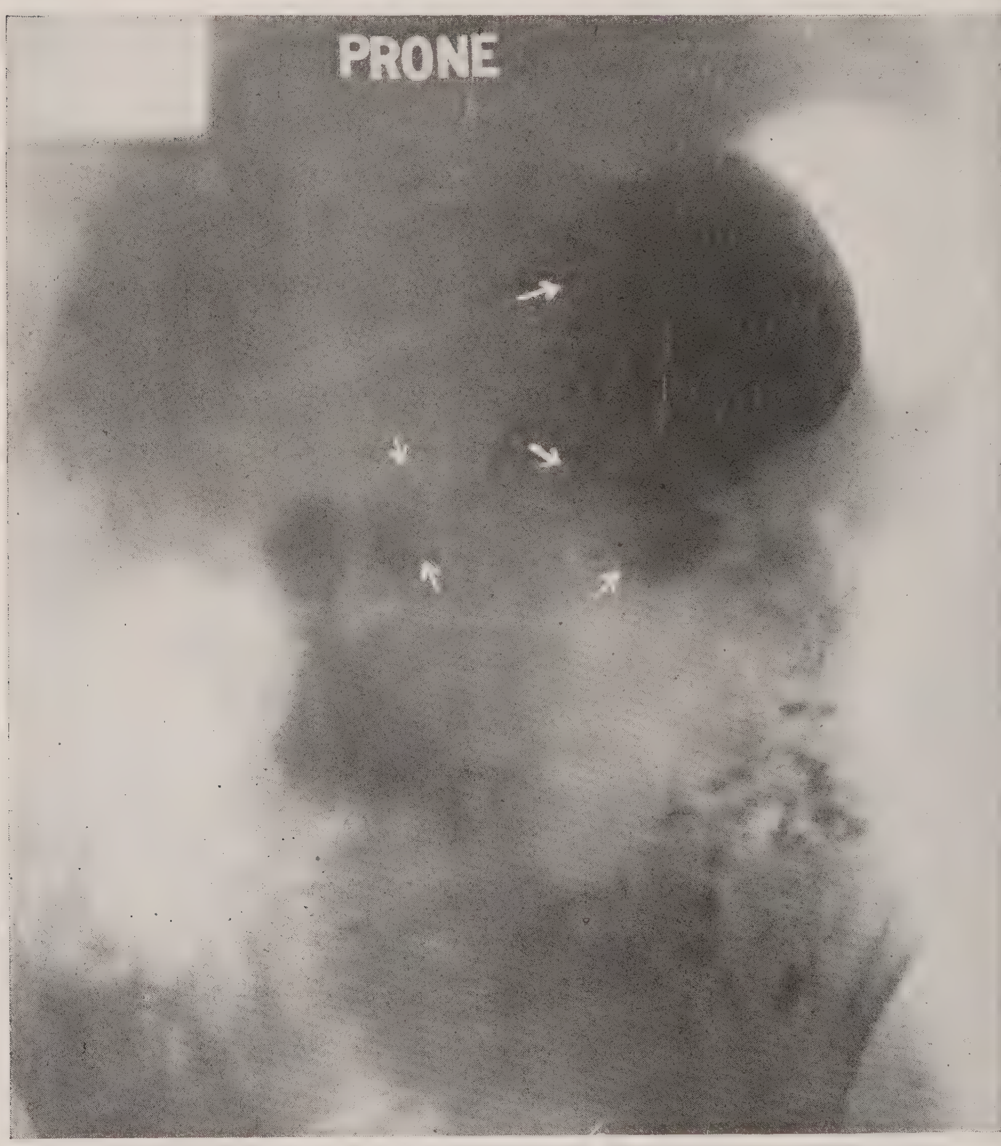


Fig. 203. Large carcinoma of stomach. The large filling defect is indicated by arrows.

sults either from spasm, cicatrization, adhesions, or from the excavation of the duodenal wall by the ulcer. Fig. 205

2. Gastric Hyperperistalsis and Hypermotility.—In simple, uncomplicated cases these two signs are usually

FIG. 204. Carcinoma of stomach, moderate size, indicated by bracket.

observed together. In acute cases they are practically the only signs.

3. Obstruction.—In chronic cases the marked scar formation may so encroach upon the lumen as to cause vary-

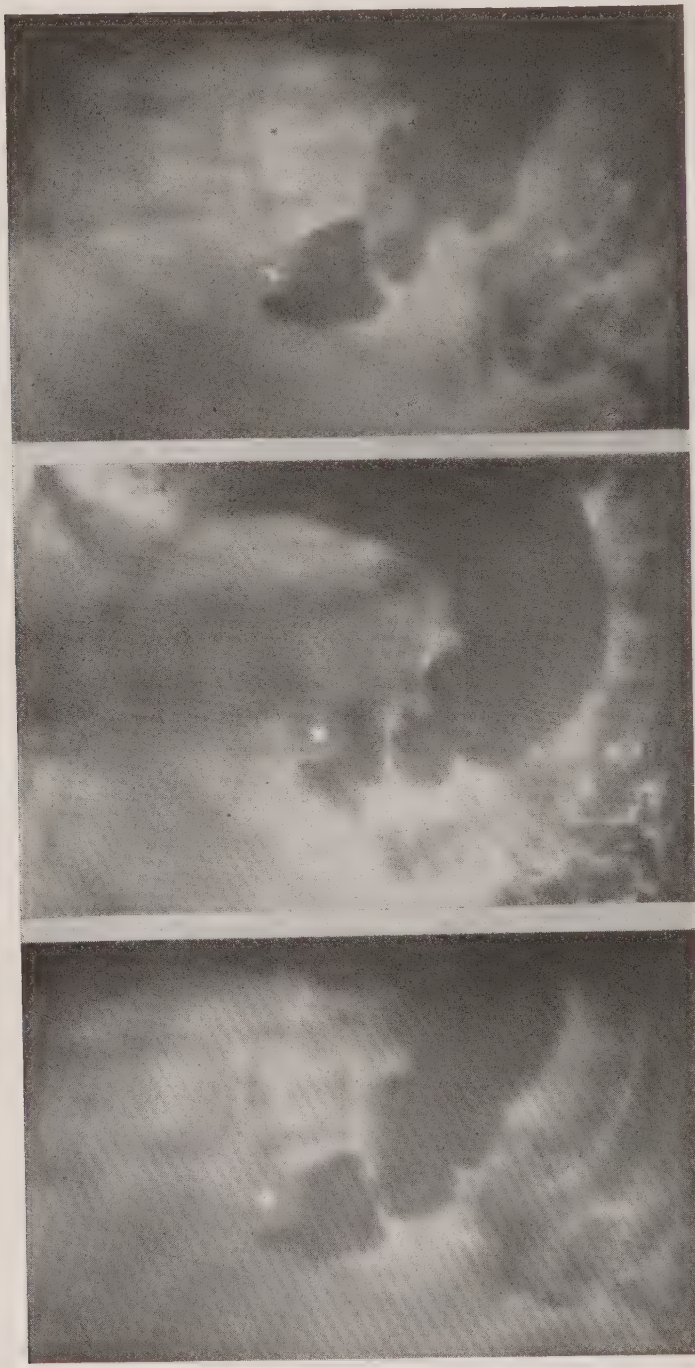


FIG. 205. Duodenal ulcer, showing defect in duodenal bulb which, though persistent, is not always of same size. Arrows indicate the defect.

ing degrees of obstruction and to delay the emptying time of the stomach.

The most important lesions in the *jejunum* are angulation, which will be discussed later under adhesions, and gastrojejunal ulcers, sometimes seen after gastro-enterostomy. Neither of these lesions occurs frequently.

In the *ileum* the most frequent abnormality is stasis. This is due mainly to two causes. The first is kinks and adhesions, the second is reflex spasm in cases of chronic appendicitis. Kinks and adhesions are usually situated about two to six inches from the ileocolic valve. Spasm is observed in the extreme terminal portion of the ileum, almost at the valve. Kinks and adhesions persist at the same place no matter what the position of the patient is. Angulations may be noted but, unless they are obstructive, they are of no importance. The most extreme degree of stasis occurs in tuberculous peritonitis due to adhesion throughout the abdominal cavity.

Colon.—Conditions of the colon which lend themselves best to x-ray study and observation are:

Mucous colitis, diverticulitis, malignancy, obstruction, constipation, adhesions and chronic appendicitis.

Mucous colitis is characterized by remains of the opaque meal, incorporated in shreds of mucus-producing material, casting string-like shadows. They are most commonly seen in the descending colon, Fig. 206.

Diverticulitis is characterized by small circular shadows beyond the lumen of the colon, seen during the progress and after the evacuation of the barium meal, Fig. 207.

Malignancy is characterized by filling defects, Figs. 208 to 210. This may be either annular or limited to one side of the lumen. The filling defect may be seen after the ingestion of the barium meal, but is best shown in the majority of cases by means of an opaque enema. Whenever

FIG. 206. Mucous colitis shown by stringy shadow of barium in descending colon and in sigmoid. Note also marked spasticity of colon up to splenic flexure.

FIG. 207. Diverticulitis; note nearly circular shadows seen in transverse and descending colon.

Fig. 208. Carcinoma of ascending colon (ingested meal). Arrow indicates growth.

a filling defect is observed it is wise to repeat the examination for confirmation, because such a defect may be simulated by spasm or by the local retention of feces not containing opaque material.

Obstruction.—In acute obstruction the site of the lesion

FIG. 209. Carcinoma of hepatic flexure (enema). Arrow indicates growth.

may frequently be determined without the administration of barium by the distended gas-filled bowel above the lesion. The opaque meal is absolutely contra-indicated and, when the opaque enema may have to be employed, it should be used with the greatest care.

FIG. 210. Carcinoma of cecum (enema). Arrows indicate growth.

Partial Obstruction.—This condition is seen in growths and adhesions, and varies according to the degree of the encroachment upon the lumen. Dilatation and obstruction should be looked for. The opaque meal and enema should be used, especially the latter.

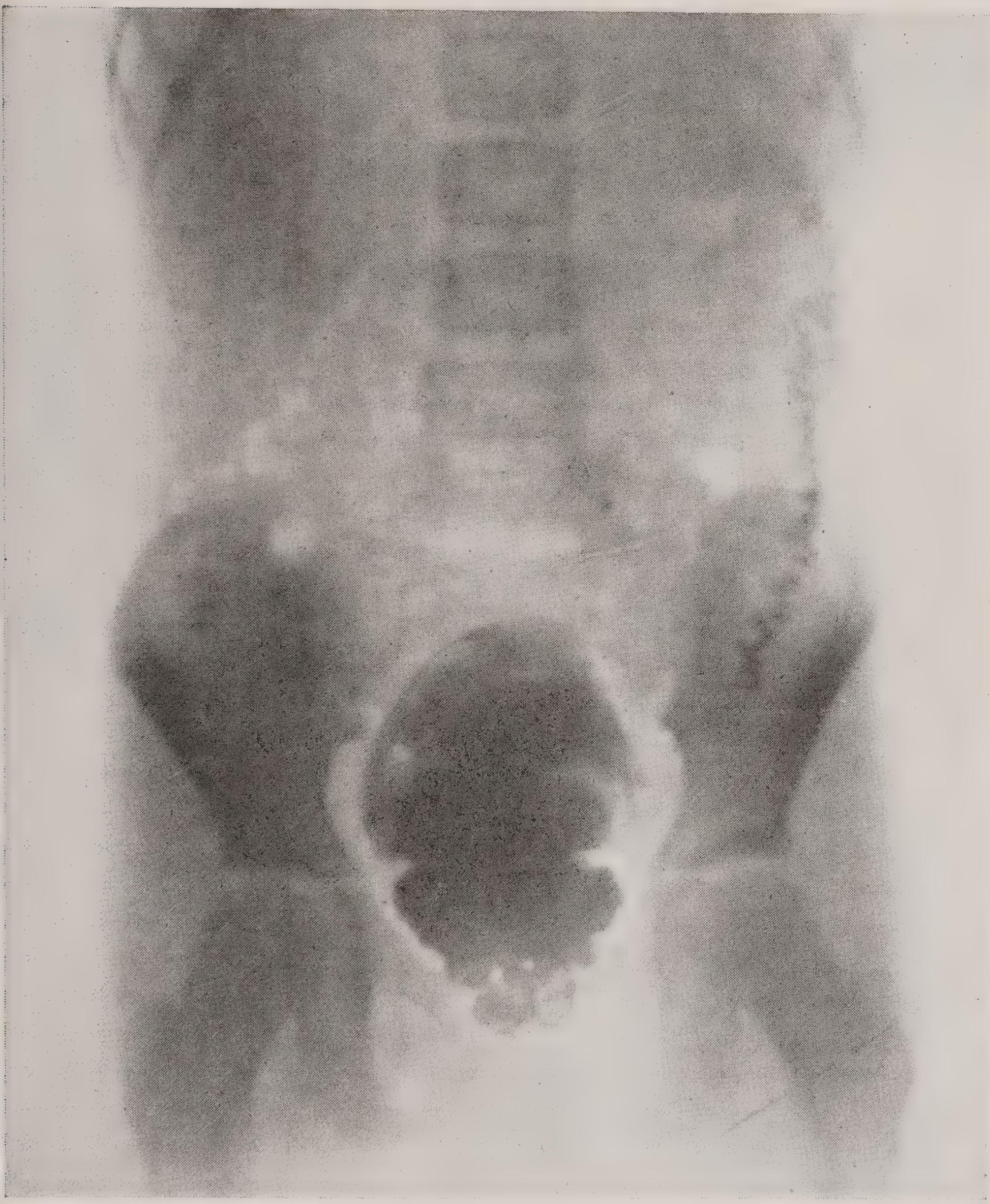


FIG. 211. Dyschezia; note dilatation of rectum (ingested meal).

Dilatation, distal to the lesion, is occasionally seen in patients who have been in the habit of taking enemata. In these cases the sigmoid and rectum are especially affected.

Constipation may be due to obstruction or may be func-

tional. The obstructive varieties have already been discussed in the preceding paragraphs. The functional variety is best studied by the ingested meal. Two principal types are recognized, the *atonic* and the *spastic.* The *atonic* is mainly cecal and is characterized by dilatation of the cecum with marked retention for forty-eight hours or longer. Spastic constipation most frequently involves the transverse or descending portions of the colon or the rectum. In the rectal type, known as dyschezia, the meal rapidly passes through the colon into the rectum, and stays there for days, gradually producing dilatation of the rectum, Fig. 211. Spasm is characterized by the absence of a continuous shadow of the barium, by a diminution in the size of the haustral segments and by an increase in the depth of the sulci.

Adhesions may be observed in any part of the gastro-intestinal tract, but are more commonly found at the following points: Stomach, duodenum, duodenojejunal junction, terminal ileum, cecum, ascending colon, and the sigmoid. They may be due to developmental bands or be the result of inflammatory processes. In adhesions at the duodenojejunal angle there is dilatation of the duodenum, Fig. 212, and reverse peristalsis after digestion is well established.

In the other regions mentioned above, fixation is the characteristic feature and is best ascertained by palpation under the screen. These adhesions may distort the part so as to cause varying degrees of obstruction.

In the sigmoid, obstruction is less frequently due to adhesions, but rather to a long mesentery which allows the sigmoid to drop forward, producing an angulation.

Lower Right Quadrant.—In addition to the above-mentioned lesions, which may occur here, especial attention

FIG. 212. Angulation at duodenojejunal junction, causing marked dilatation of third portion of the duodenum.

should be directed to the appendix and its relation to cecum and ileum.

The diagnostic value of the filling or nonfilling of the appendix is still a debatable point. When the appendix is

FIG. 213. Appendix. (Appendix filled with barium.)

visualized observations should be made with reference to:

1. *Size.*—This is of relatively minor importance.

2. *Position.*—When the appendix is curled upon itself, retro-cecal, or its tip is adherent to the ileum or cecum,

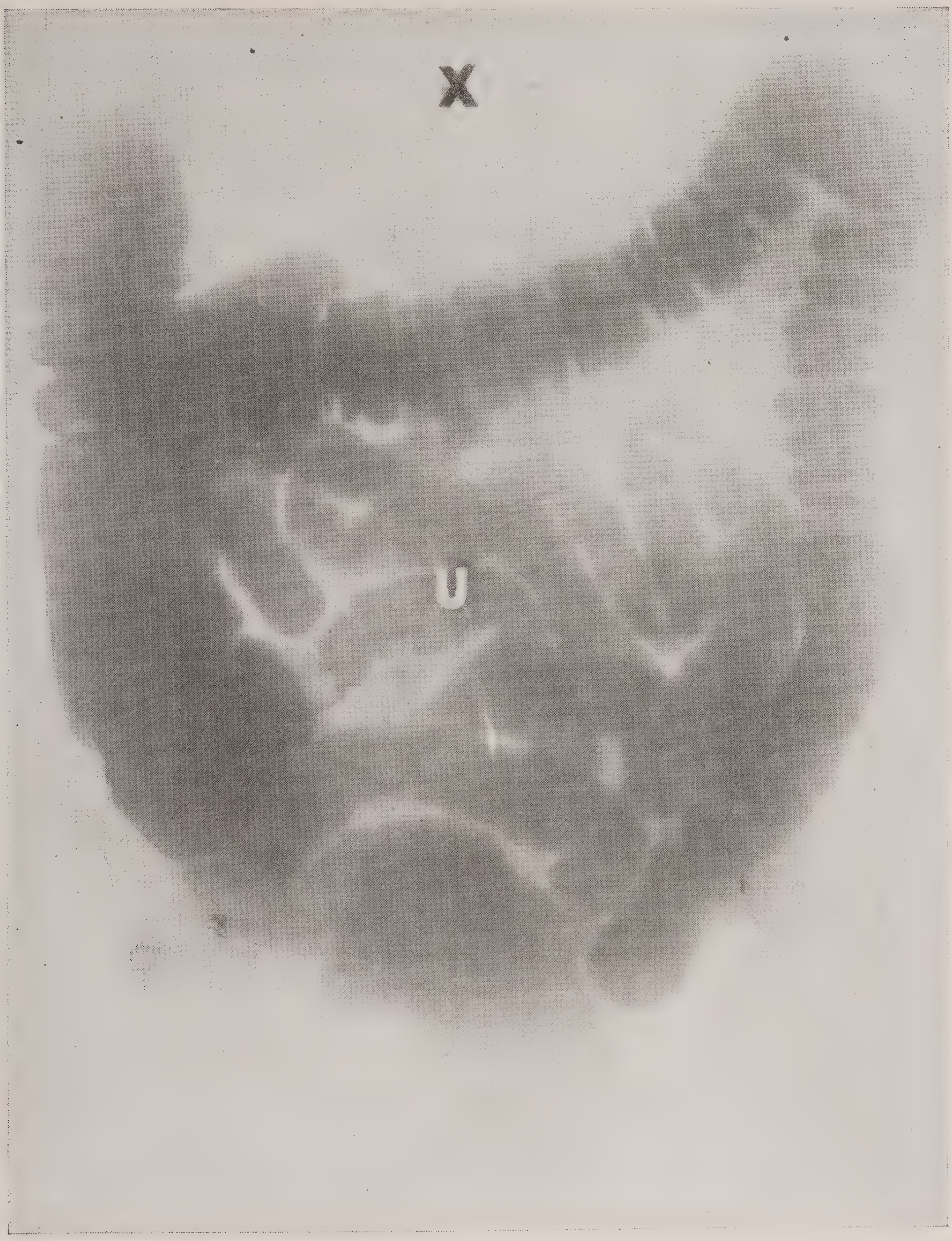


FIG. 214. Incompetency of ileocecal valve. Note filling of small intestines around U. *X*—marker placed on rib of ensiform. *U*—marker placed on umbilicus.

FIG. 215. Gall-stones. Visible because of presence of calcium salts.

it may be regarded as pathological. Mobility and fixation are best determined by palpation under the screen.

3. *Segmentation.*—This is generally regarded as an indication of previous inflammation.

4. *Tender Spot.*—Tenderness elicited over the region of the appendix generally means a pathological condition in this area and is of especial value when the appendix is not visualized.

5. *Retention in the Appendix.*—Fig. 213. Some authors claim that retention in the appendix after the cecum is empty indicates a pathological condition. Other observers, however, lay more stress upon ileal retention.

The lower right quadrant is best studied by means of the opaque meal at the time the cecum is filling. The opaque enema is of no value except in the determination of the position of the cecum or of the competency or incompetency of the ileocecal value, Fig. 214.

Gall-Bladder.—The pathological lesions which are sometimes observed are calculi, adhesions, and distension-producing deformities in neighboring organs, especially the duodenum.

Calculi.—Those containing a fair amount of calcium salts are easily recognized by their nearly circular outline, the comparatively dense border and the more or less transparent central portion, Fig. 215. Unfortunately these form a relatively small percentage of the total number of gall-stone cases. Those which are composed of pure cholesterin are difficult to demonstrate. At the present day, their recognition is a much debated question. It is not in the scope of this manual to discuss the claims of various observers upon this subject. A safe rule for the beginner to follow is not to diagnose gall-stones, except when distinctly shown and, conversely, not to exclude their presence, if none have been demonstrated on the plate.

Adhesions occur most commonly between the gall-bladder and duodenum. They can be recognized by palpation under the screen after an ingested meal. In this condition

the duodenum will be fixed in the upper right quadrant region and its outline will sometimes be irregular.

A *dilated gall-bladder* occasionally may be visualized, but more often its presence is detected by deformities in neighboring organs, especially in the duodenum. The deformity in the duodenum may closely simulate that produced by an ulcer. When due to pressure from the gall-bladder it is usually not accompanied by the gastric manifestations seen in ulcer. Sometimes it is impossible to differentiate the two conditions.

MEASUREMENT OF X-RAY DOSE

The measurement of the radiation from an x-ray tube has been the subject of much discussion and only partial agreement as to the methods that should be employed has been attained to date. A satisfactory method would enable an observer to determine the amount of radiation delivered by the tube in a simple and effective manner, and would enable others to reproduce results without requiring unusual skill or loss of time.

It is certain that a proper measurement of current, effective voltage at the tube terminals, time of exposure, distance between target and skin, nature and amount of filtration through which the rays pass before reaching the skin give all the data necessary for the reproduction of x-ray dose. This method, however, has not appealed to the profession as yet, partly because there is no record actually produced by the radiation to which the attention of the physician or his assistant may be directed. A statement, however, of the approximate conditions under which fairly well established doses may be obtained is of considerable service as supplementing the reading by radiometers.

Of the various effects produced by x-rays only two have found a reasonable amount of favor as a basis for measurement. These are (1) the effect upon the photographic emulsion, (2) the color change of platinum barium cyanide crystals when exposed to the radiation. The latter, or pastille method was first proposed by Saboraud and Noiré who established a color to be attained by the pastille when it receives an amount of radiation sufficient, generally, to

produce a slight inflammation of the skin or an "erythema" dose. The method was further studied by Holzknecht, Hampson, and others, partly with the idea of enabling one to read fractional doses. In order to do this it is necessary to have a scale of colors or tints corresponding to those attained by the pastille in various stages of exposure. In using the pastille method there are several precautions which should be observed. Among these may be mentioned the following:

(a) The pastille will change from an apple green tint toward the brownish yellow produced by the action of x-rays under the action of bright sunlight or heat, or even in an extremely dry atmosphere. For this reason the pastille should be kept in a suitable, ventilated humidor in diffuse daylight and not near radiators or other heating devices.

(b) After use, when placed in an ordinary moist atmosphere, not in heat or bright sunlight, or in strong artificial light, the pastilles tend to regain their original unradiated tint though they rarely completely recover. For this reason the reading should be made *immediately* after exposure and the result recorded.

(c) Inasmuch as the tint reading depends upon an accurate perception of color difference the method is unsuitable for people who are partially color blind, especially in the green. Also since the pastille cannot reflect light to the eye that it does not receive, it must be read in a fairly standard illumination. The best light available for this purpose is that from a low power carbon filament lamp; the observation should be made by reflected light and the eyes shielded from direct illumination from the the lamp. Care should be taken that the gloss or sheen of the pastille does not confuse the reading.

(d) There are two positions used by different observers

for exposure of these pastilles. They may be placed either on the patient's skin where the radiation strikes or half-way between the skin and the target. The amount of skin dose indicated by the same change of color of the pastille placed on the skin is four times as great as when the pastille is at the half-distance point. The advantage of the skin position is certainty of distance from target to skin. A slight error in estimating the distance from the target to the skin for comparison with the pastille at the half distance may introduce a relatively large error in dosage. Also the moderate changes of color are read more accurately than the extreme changes, partly because they change less rapidly after exposure.

(e) While a pastille may be used a second or third time it is unwise to do so. It is far better to depend on electrical measurements, time and distance than to use a poor pastille or radiometer.

(f) The comparison tints of a radiometer are not permanent and two of the same make rarely agree. The Hampson O will rarely agree with the tint of a fresh pastille and if too yellow the pastille must be brought to agree with a low numbered scale tint before use. The reading is then made by subtracting the number before treatment from that of the match tint after treatment. Thus if the pastille matches tint 3 before and number 7 afterwards the dose is 4 Ha.

The photographic method has generally been spoken of as the Kienböck method and involves the use of a photographic paper of the proper degree of sensibility. It is essential:

(a) That the paper should be uniform in sensibility and carefully kept.

(b) That development be carefully attended to with reference to nature and concentration of developer, its

temperature and the time of development. Of these it may be remarked that variation in temperature is the most important, variation in time of development is next, and within reasonable limits concentration of developer has little effect. The advantage of this method lies in the fact that it gives, when properly done, a permanent record

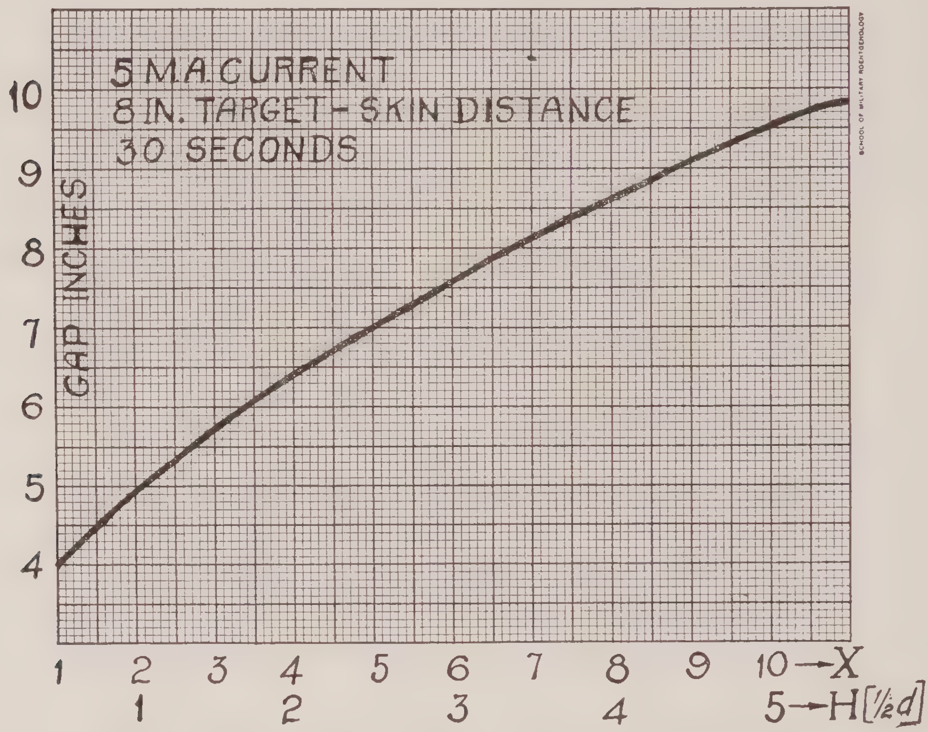


FIG. 216. Dosage curve for various spark gaps.

of superficial dose. The disadvantages are variation in sensibility of paper (which are, however, no greater than that of pastilles), and the need of care and attention in development.

The paper method is extremely useful in determining whether or not an x-ray operator is receiving more than a safe amount of radiation. It is superior to the pastille for this purpose, owing to the fact that it may be carried for a considerable period of time attached to the clothing,

if properly protected from light, and be unaffected by anything excepting the x-rays received. A scale in X units may be readily worked out using the data of curve, Fig. 216, and it will have very much the appearance of Fig. 52 for determination of the sensibility of intensifying screens. Inasmuch as 10 X corresponds to an erythema dose, it is very easy to make such a strip in which the different portions will receive from 1 to 10 X units. If a series of small pieces of this paper are placed in a light proof container transparent to x-rays and attached to the clothing in regions likely to receive either direct or scattered radiation or both, they may be removed, one at a time, at successive intervals and developed under the same conditions prevailing when the scale was made and the rate at which radiation was received per hour determined.

(See also chapter on dangers and protection, page 194.)

It must be understood that the radiometer gives an indication of the radiation it absorbs from the incident beam and does not tell how much is going to reach any given depth. This will be dependent upon the voltage at which the tube is operated and upon the amount of filtration between the target and the skin.

The radiometer available in the army base hospital at present is the Hampson. A graded series of tints is mounted on a circular disc that revolves past a small opening. These tints are numbered from 0 to 24 and a match is to be made by placing the radiated pastille as near as possible to the opening where the tints appear and rotating the disc. Instructions will be found with the instrument. If the pastilles supplied are brownish or yellow instead of pale green they are old and have not been properly kept. It would be safer to use the data of Fig. 216 carefully adjusting for current and gap rather than to depend upon poor pastilles.

If the reader desires to translate instructions for therapy from one scale to another the relations are as follows, assuming that we have a fresh pastille:

	Designation	Author	Position of pastille on strip
Erythema Dose	Tint B	Saboraud	½ target skin distance
	5 H	Holzknecht	½ target skin distance
	1¼ H	Holzknecht	Pastille on the skin
	10 X	Kienböck	Strip on the skin
	4 Ha	Hampson	Pastille on the skin
	16 Ha	Hampson	Pastille at ½ distance.

The curve, Fig. 216, shows the *unfiltered* dose when 5 ma., 8 inches target skin distance, is used for 30 seconds, for various spark gaps between moderately blunt points. The time may be varied to compensate for any current that may be used with the selected gap. Thus at 10 ma., 15 seconds will be required, at 3 ma., 50 seconds, etc.

CUTANEOUS X-RAY THERAPY

Not to be Administered by the X-ray Manipulators Under any Circumstances

Explanations.—In this chapter Holzknecht units are estimated with the pastille on the skin; symbol H.

Filtration.—Aluminum 3 mm. Dose estimated with pastille on skin and covered with the filter.

Erythema Dose.—Synonyms: skin toleration dose; epilating dose: skin unit. A quantity of ray sufficient to produce defluvium of scalp hair. The same quantity will provoke erythema on most parts of the cutaneous envelope. Expressed in figures: 1¼ H; 4 Hampson; 10 X.

Intensive Treatment.—Single exposures, at monthly intervals, to one area, of quantity ranging from H 1 to H 2 unfiltered and from H 2 to H 3 filtered.

Semi-intensive Treatment.—H ½ at intervals of 2 weeks (H 1 filtered).

Fractional Treatment.—H ⅛ or H ¼ once or twice weekly (H ¼ or H ½ filtered).

Quality.—The majority of skin diseases respond better to rays of comparatively short wave length. For routine technique employ a spark gap of 6 or 7 inches. For filtered treatments use a 9-inch gap.

Protection to Patients.—Protect healthy skin, testicles, hairy parts, etc., with lead foil or other suitable material containing an aperture the size of the lesion.

Radiodermatitis.—*Definition.* A reaction on the part

of the skin (and subcutaneous tissue) to the influence of the x-ray. Divided into 3 degrees.

First Degree.—Erythema which may be faint and transient; or pronounced, enduring for several weeks and accompanied by burning, stinging, itching and temporary or permanent loss of hair. Frequently leaves pigmentation which may persist for many months.

Second Degree.—Erythema, exfoliation, vesiculation, excoriation, exudation and burning pain. Requires several weeks to heal.

Third Degree.—All the second degree symptoms, ending in indolent ulceration with destruction of true skin, subcutaneous tissue and even the muscles. Excruciating pain. Requires months and even years to heal.

Severe Reactions.—These usually appear a day or two after exposure. Conversely, mild reactions are first manifested from 7 to 10 days subsequent to the treatment. This is not always so. The reverse may be true.

Delayed Reactions.—Occasionally a reaction does not appear until after a lapse of 3 or 4 weeks.

Electrical Erythema.—This is an erythema occurring within from 3 to 8 hours and lasting a day or two. According to Pfahler it can be avoided by grounding the lead foil used to protect the normal skin.

Sequelæ.—A single occurrence of a simple erythema may give rise, 6 months or a year later, to telangiectasia, atrophy and alopecia. Therefore erythema of the exposed parts should be avoided. Second degree reactions usually leave atrophy, telangiectasia and alopecia. Years later keratoses may develop. Repeated erythema also may effect these sequelae. Third degree reactions may never heal. If they do the resulting scar is unhealthy, even dangerous.

Etiology.—With the exception of idiosyncrasy and acquired susceptibility the cause of radiodermatitis is ex-

cessive dosage. It is a question of quantity, not of quality.

Idiosyncrasy.—True idiosyncrasy is a very rare phenomenon. Acquired hypersusceptibility is common. To avoid unexpected reactions observe the following rules:

1. Technique must be in accordance with modern requirements.
2. Unless specifically indicated avoid large doses.
3. Allow sufficient time between doses.
4. Very young individuals react more vigorously than do old people. The skin of brunettes is less sensitive than that of blonds, that of females a little more than that of males.
5. The flexor surfaces are more sensitive than the extensor surfaces. The flexures and skin over the joints are very sensitive. The face is exceedingly sensitive.
6. Chemicals such as mercury, iodine, tar, iodoform, chrysarobin, sulphur, etc., applied before or after treatment markedly enhance the influence of the ray. At times this effect may endure for weeks and months.
7. Skin affected by certain diseases—psoriasis, eczema, acute lichen planus, mycosis fungoides—is hypersensitive.
8. Acute inflammations and the congestive dermatoses react more severely than do lesions containing a poor blood supply or those that are covered by a thickened horny layer.

Treatment.—There is no known practical procedure that will prevent, modify or abort a reaction after the treatment has been given. Nor is there any way to avoid the development of sequelæ. First degree: Use 10 per cent zinc oxide ointment. Second degree: Use wet dressing of aluminium acetate; do not allow exudate to come in contact with normal skin—severe, generalized, exudative eczema may result. Third degree: If deep and indolent, excise

the area. Otherwise, use wet dressings or a 10 per cent zinc oxide ointment containing 1 per cent of ichthyol. For the pain, 10 per cent of anesthesin may be added to the ointment or wet dressing.

Biology.—The x-ray exerts its greatest influence on cells that are either physiologically or biologically very active. The nearer a cell approaches the embryonic type (the more recent its development) the greater is its susceptibility to the x-ray. This explains the profound influence of the ray on the function of the ovary and testicle, also on the glandular structures of the skin, the germinating layer of the epidermis, etc. Many cutaneous diseases consist, histologically, of a rapid multiplication of cells—these active cells are likely to be easily influenced by the ray. Bacteria are not affected by practical doses. The soil, however, may be so modified as to interfere seriously with bacterial development.

Bragg advances the theory that the biologic action of the x-ray or gamma ray depends upon ionization—a dissociation of the elements comprising the cell—also, that most of this ionization is accomplished by the corpuscular secondary rays (beta rays) formed in the tissue. These rays are a product of the primary beam, of the scattered rays and of the characteristic rays. It may be, therefore, that the sole purpose of the x-ray is to penetrate the tissues and produce beta rays at the desired depth.

Stimulation and Inhibition.—As shown by botanical experiments small doses at long intervals stimulate embryonic tissue; large doses inhibit and destroy. This knowledge can be utilized in the application of x-ray to disease.

Diseases and Conditions

Eczema.—The x-ray is of benefit in practically all but the very acute types of this affection. Subacute or chronic

eczema, whether squamous or exudative, especially when occurring in patches, yields with amazing rapidity. Seborrheic eczema and chronic occupational eczema also are markedly benefited. The lesions of eczema disappear under the influence of the ray but the disease itself remains unaffected.

Technique.—Fractional. H 1/8 once or twice weekly. If this does not cause involution in 2 or 3 weeks, do not increase nor persist in the treatment.

Psoriasis.—Psoriasis of any type yields promptly, as a rule, to the x-ray.

Technique.—Widely separated patches are to be shielded closely and treated individually; fractionally or semi-intensively. Generalized eruption necessitates treatment of most of the body surface including normal skin between lesions. Divide body into sections as follows: 1. Scalp, face, neck. 2. Chest, abdomen. 3. Dorsal back, lumbar back, buttocks. 4. Thighs (4 surfaces). 5. Legs and feet (2 surfaces). 6. Arms, forearms and hands (2 surfaces). To avoid overlapping, mark dividing lines with a skin pencil. Expose one section daily with fractional dose of H 1/8. No one section is to receive more than one treatment in one week. After the second week, if improvement is not satisfactory, increase to H 1/4. If disease is not under control in four or six weeks discontinue treatment. When the lesions have disappeared stop treatment—do not treat the remaining stains. If, during treatment, a toxic rash appears, discontinue treatment immediately. The scalp is to be treated in accordance with the Kienböck-Adamson method (see page 480), the dose being as above stated. For the face the tube is placed first over the zygoma on one side and then over the other side. Scalp, eyes, eyebrows and eyelashes must receive protection. The neck will receive enough ray from the scalp and face treat-

ments. In treating section 2 place tube consecutively over a point a little outside and above one nipple, same position on other side, 5 inches to one side of umbilicus and same distance to opposite side. Allow the rays from these treatments to overlap, but do not allow one section to overlap another. Apply same general scheme to treatment of section 3. Anterior, posterior and lateral surfaces of thighs often must be exposed. In treating these the surface angle of incidence of one exposure should be at right angles to any other. The flanks will receive sufficient ray from the back and abdomen exposures. When extremities are very long it may be necessary to make two exposures to one surface. For example, a long thigh, the tube is first placed over the upper part and then over the lower part, the rays being allowed to overlap in the center. In such instances the exposures should be 10 inches apart. X-ray cures the lesions not the disease.

Dermatitis Exfoliativa.—This is often secondary to eczema or psoriasis—when these diseases become universal. This type usually responds well to technique outlined for psoriasis. The primary type is more recalcitrant, but often undergoes involution under x-ray therapy.

Lichen Planus.—This disease causes severe itching which is exceedingly difficult to control. Under ordinary dermatological treatment from three to eight months is required to effect a cure. X-ray treatment will usually afford prompt relief from the itching and will make the eruption disappear in from two to eight weeks.

Technique.—Chronic localized patches are shielded close and treated fractionally (H 1/4 once weekly) semi-intensively or intensively. A single intensive dose of H 3/4 to H 1 will often suffice. Acute generalized lichen should be managed as generalized psoriasis. The dose must be small; H 1/8.

Lichen Chronicus Circumscriptus and Lichenification.—These affections respond promptly to fractional doses of H 1/4 weekly.

Pompholyx (Dysidrosis).—Fractional treatment is of distinct service.

Clavus, Callositas, Verrucæ.—Corns (hard or soft) respond to from 1 to 3 intensive treatments. Remove horny layer with razor, shield very close and apply H 1. If horny layer is still thick after use of razor H 1½ may be applied. The exceedingly painful, so-called plantar wart responds, as a rule, to one or two treatments. The technique is the same as in the treatments of corns. If three treatments do not result in a cure advise some other form of treatment. The common wart (verruca vulgaris) usually responds to one intensive treatment of from H 1 to H 1½. Shield very close. Do not give more than two treatments. The flat wart (verruca planum) does not respond well to radiotherapy. Senile warts (verruca senilis, verruca seborrheica, etc.) disappear as a result of a single treatment of H 2 providing the horny layer is first removed. These lesions are potentially dangerous, therefore they must not be stimulated. Do not shield too close.

Keloids, Hypertrophic Scars, Cicatricial Tissue, Etc.—With the exception of radium the x-ray is the only means of successfully treating a keloid. Small recent keloids disappear in one or two treatments. Large, hard, old keloids may require eight, ten or twelve treatments. Spontaneous keloids are less recalcitrant than are those developing secondary to definite trauma. Hypertrophic scars and cicatricial bands can be softened, reduced and even completely absorbed.

Technique.—Shield right up to the very edge of the lesion. Employ the intensive, filtered technique, but do not cause an erythema. If the first treatment provokes a vis-

ible reaction, reduce the size of the subsequent doses. If lesions are small, filtration is not necessary. In cases where eight or ten treatments are required care must be taken not to produce an x-ray skin. This can be done by avoiding erythema and by allowing intervals of two or three months between treatments. If the lesion is very large and pedunculated, it should be excised and x-ray used as a prophylactic. Do not administer the x-ray immediately after the operation—allow an interval of two or three weeks. Fractional and semi-intensive treatments, also, give good results in keloidal tissue.

Plastic Surgery.—Quite recently Percival Cole and Knox have found the x-ray of service in preparing gunshot wounds for plastic operations. In extensive wounds, especially those involving the orifices, there is formed considerable thick, inelastic cicatricial tissue. This tissue is rendered considerably softer by from one to three intensive treatments.

These authors have also employed the ray to depilate hair when a flap of skin is going to be utilized to replace the destroyed lining of a cavity such, for instance, as the mouth. It is necessary in such instances to effect permanent alopecia and this must be done without too much injury to the skin. It is practically impossible to produce a permanent alopecia without a little atrophy, and we may even get a little telangiectasia. These sequelæ are of no importance. But repeated reactions of the first degree and a single reaction of the second degree must be avoided. It is preferable to avoid even a first degree reaction. If only a small flat area of the bearded region is to be used as a flap, and this is generally the case, one treatment (H 1¼ filtered through 1 mm. A1., 7 to 9-inch spark gap) will usually make the hair fall out, but it may also provoke an erythema. There is less likelihood of a reaction if this

amount of x-ray is divided into fractions and administered during a period of two or three weeks. After the defluvium it is necessary to administer H 1 monthly or H ½ bimonthly for from three to six months to insure against a regrowth of hair.

Tuberculosis.—This disease is multiform in its cutaneous manifestations, and these various manifestations are divided into a number of clinical entities, as follows:

Lupus Vulgaris.—Atrophic, hypertrophic and ulcerative. The hypertrophic and ulcerative forms do very well under x-ray treatment. It is possible to obtain a permanent cure. The atrophic type is exceedingly rebellious.

Technique.—Intensive.

Lupus Erythematosus.—Discoid and disseminate. Occasionally this disease (which is not true tuberculosis) will respond to the x-ray; usually it will not do so. A larger percentage of cases yield to the more penetrating radium beta rays; and these rays often fail. The discoid type is less recalcitrant than is the disseminate type. The disease when "cured" always recurs.

Technique.—Fractional, semi-intensive or intensive in the discoid form; fractional in the disseminate type.

Caution.—Remember that both lupus vulgaris and lupus erythematosus yield slowly—that considerable treatment is required. Remember, too, that both these diseases leave a scar in which cancer is prone to develop. Therefore do not persist in the treatment of the lesion, if it does not yield to a few mildly intensive treatments or the equivalent in fractional doses. Do not produce an x-ray skin.

Tuberculosis Verrucosa Cutis (Warty Tuberculosis—Anatomical Tubercle).—This affection usually undergoes involution rather promptly under the influence of intensive treatment. If the verrucose element is marked use a filter. A permanent cure may be expected.

Bazin's Disease and Sarcoid.—Good results may be obtained by fractional, semi-intensive or intensive filtered treatments, preferably the latter.

Tuberculosis Orificialis.—Tuberculosis of the orifices usually does well under x-ray therapy—intensive doses. Because of the location, radium is often preferable. Relapses are common.

Tuberculous Adenitis.—Good results may be expected in a fair percentage of cases.

Technique.—Intensive or semi-intensive filtered treatments. In cervical adenitis do not provoke an erythema because of the possibility of subsequent telangiectasia.

Epithelioma.—Basal cell (rodent ulcer) and squamous cell (malignant). In the basal cell type a permanent cure may be expected in from 85 to 90 per cent of unselected cases. The result is always doubtful in the squamous cell type. If the basal cell type is given a preliminary curettage a cure can usually be obtained in one or two treatments. It is unwise to curette the squamous cell type because of the danger of metastasis. The lesion should be removed by a wide excision and the entire region and neighboring glands given several intensive filtered treatments.

Technique.—Very intensive (H 2 or H 2½ unfiltered). If the lesion is markedly infiltrated and is not curetted, employ a filter . Always include a wide area around the lesion. Do not stimulate. Stimulation can be avoided by intensive treatment, by curettage, by cross-fire when possible, filtration when desirable, and by dividing large lesions into from 2 to 4 squares and applying an intensive dose to each square. If a full dose is administered to the center of a large lesion, the margin may be stimulated (intensity inverse as square of distance). In deep lesions, on account of absorption, the lowermost cells may be stimulated unless lesion is curetted, a filtered ray is employed or the

cross-fire method (administration of full doses to a tumor from two or more directions) utilized.

Sarcoma.—As in epithelioma, there are benign and malignant forms of sarcoma. The benign types (Kaposis sarcoma, the Speigler type, etc.) usually respond readily. The malignant types frequently do well if stimulation is avoided. The technique is the same as in the squamous cell sarcoma.

Mycosis Fungoides.—The lesions of this terrible disease, both in the premycotic and the fungoid stages, disappear in the most surprising manner under the influence of the x-ray. In fact they undergo such prompt involution that caution must be exercised in order to prevent systemic toxemia. The distressing itching is usually relieved at once. The disease cannot be cured, but it is often possible, by occasional treatment, to keep an individual alive and comfortable for many years.

Technique.—The technique is the same as that described under psoriasis. The dose at first should be very small (H 1/16 to H 1/8). Later this may be increased to H 1/4. If a toxic rash appears or there are any symptoms of toxemia, discontinue treatment at once. After these symptoms disappear begin again and proceed cautiously. When the disease is under control, and one or two lesions develop at long intervals it is permissible to employ a mildly intensive technique.

Acne Vulgaris.—The x-ray is a specific in this disease and is indicated in obstinate cases. The technique is fractional. An erythema is not permissible.

Acne Varioliformis.—Fractional doses are helpful in this affection.

Sycosis.—Sycosis vulgaris (staphylogenic sycosis) and sycosis parasitica (sycosis barbæ; ringworm sycosis). In the bacterial type it is surprising how promptly a long-

standing case will respond to a few fractional treatments. At times, however, it is necessary to effect a defluvium of the affected area. Relapses are common. X-ray treatment is equally efficacious in the parasitic type excepting that here it is always necessary to effect epilation.

Technique.—Parasitic sycosis usually exists as one or several isolated, well-defined areas. Apply a single epilating dose (H 1) to each area. Sycosis vulgaris is likely to involve the entire bearded region and the upper lip. Apply fractional doses in the following manner: Place the anode over mandible of both jaws and over the point of the chin with the head extended. Each treatment is at right angles to the others and the anode is always the same distance from the skin. Protect the mucous surfaces of the lips, the nose, eyes, eyebrows, and scalp. Apply H ¼ every five days until H 1 has been given and then stop. The hair should fall out, without erythema, a week or two later. If the lesions begin to disappear after the first or second treatment it may not be necessary to administer further treatment.

Caution.—Avoid use of sulphur, mercury, etc., before, during, and after x-ray treatment.

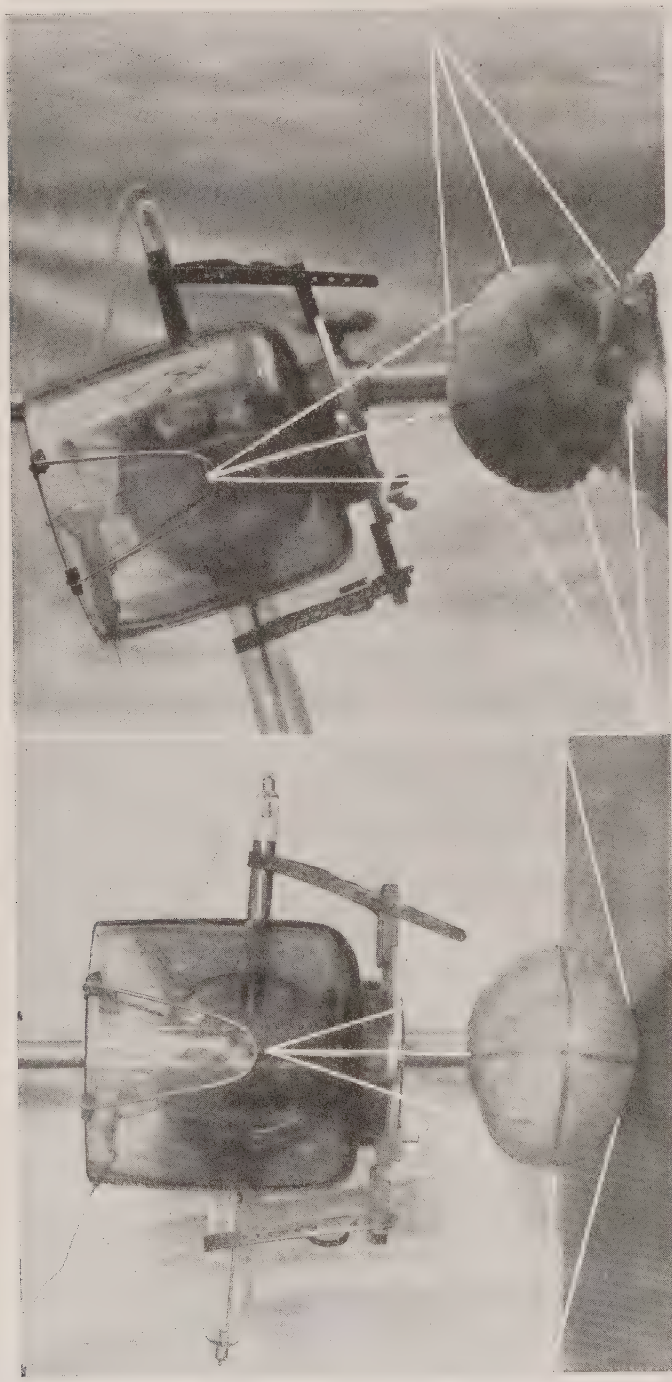
Favus.—If this contagious disease should gain headway in the army it would be necessary to treat each individual head with the x-ray. There is no other satisfactory treatment and, with a reliable technique, the result is certain.

Technique.—The method of applying the x-ray to favus and ringworm of the hairy scalp is known as the Kienböck-Adamson method. It consists of dividing the scalp into five areas and administering an epilating dose (H 1; spark-gap 7 to 9 inches) to each area at one sitting. The face, ears, neck and back are shielded. The anode must be always at the same distance and each treatment at right angles to every other treatment. The scalp is marked out

in the following manner: First, the hair is clipped close to the scalp. A mark is made in the middle line one inch inside the anterior hair line. A similar mark is made one inch inside of the posterior hair line. These marks should be exactly 10 inches apart. If not, they are adjusted so that the required distance is obtained. Then a mark is made exactly in the center of this line. Two more marks are made about one inch above and a trifle forward of the external auditory meatus. These marks are so adjusted that they are exactly 5 inches from every other mark. The requirements are:

1. Five inches between each mark.
2. Each treatment exactly at right angles to every other treatment.
3. Maintain constant anode-skin distance.
4. Accurate measurement of epilating dose.
5. Shield face, ears, neck and back.
6. Direct beam must strike each one of the five marks.
7. Allow incident rays to overlap.
8. Avoid irritating chemicals before and after treatment.
9. Remove crusts before applying the x-ray.
10. The head must be stationary.
11. Eight inches is a good working distance.

The hair will fall out three weeks subsequent to the treatment and will begin to regrow in from one to three months. It is not necessary that all the hair fall out; if most of it falls out the end result is satisfactory. There should not be an erythema. A transitory erythema (lasting a day or two) need occasion no alarm. A severe reaction is likely to cause permanent alopecia. Fractional treatment will accomplish the same result providing a total of H 1 is administered in three weeks. The accompanying



FIGS. 217 and 218. Five areas and angles of incidence of rays. Kienböck-Adamson method.

illustrations, Figs. 217 to 219, explain better than words the location of the points or marks, the overlapping of the

FIG. 219. After depilation by Adamson method.

rays, the direction of the central ray, the angles at which the treatments are given, etc. The lines between the five points aid in determining the angle for the treatments.

Onychomycosis (Ringworm of the Nails).—Sometimes this affection yields readily to x-ray treatment. At other times it is extremely obstinate and, frequently, it will not respond at all.

Technique.—Shield close; fractional, semi-intensive or intensive.

Actinomycosis and Blastomycosis.—These diseases usually involute rapidly under both fractional and intensive treatments; occasionally they do not.

Hyperidrosis.—Excessive sweating of the palms and soles can be cured by radiotherapy.

Technique.—Fractional or intensive, preferably the latter. H ¾ to H 1 every four weeks for from two to six treatments. If, after the second exposure, sweating is markedly reduced, discontinue the treatment. Do not cause complete cessation of perspiration, as skin will become too harsh and dry. In treating the palms it is possible to slightly flex the fingers and thumb so that all parts will receive an equal dose (in accordance with inverse square of distance). Pirie has devised a convex celluloid support for the hands which is a great aid in treating the palms, as the convexity is so arranged that, when the direct beam is centered, every part of the flexor surface of the palms, fingers and thumbs will receive the same amount of ray.

Pruritus.—Idiopathic pruritus ani will usually yield to fractional doses. The relief is temporary.

Chronic Ulcers and Indolent Wounds.—Indolent wounds and ulcers may at times be stimulated and benefited by fractional treatment. This is true of some examples of ecthyma, ulcers from insect bites, gun-shot wounds, varicose ulcers, etc. It is probable that better results might be obtained by means of heliotherapy or phototherapy.

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